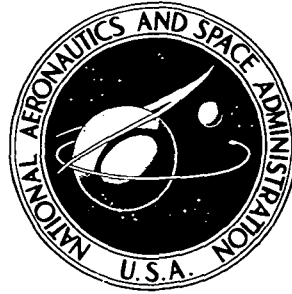


**NASA CONTRACTOR
REPORT**



NASA CR-2442

NASA CR-2442

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**PREDICTION OF SONIC BOOM
FROM EXPERIMENTAL NEAR-FIELD
OVERPRESSURE DATA**

Volume II - Data Base Construction

by C. R. Glatt, S. J. Reiners, and D. S. Hague

Prepared by

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for Langley Research Center



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16. Abstract A computerized method for storing, updating and augmenting experimentally determined overpressure signatures has been developed. A data base of pressure signatures for a shuttle type vehicle has been stored. The data base has been used for the prediction of sonic boom with the program described in Volume I.					
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PREFACE

This report was prepared under contract NAS 1-12579, "Expansion and Extension of the SBOOM Computer Program." The study was carried out during the period from July, 1973 through December, 1973. The study was funded by the National Aeronautics and Space Administration, Langley Research Center, Space Systems Division.

The study effort resulted in the development of two new computer programs, one for generating and maintaining a data base of near-field pressure signatures and the other for predicting sonic boom as a result of overflight of shuttle type reentry vehicles. The study results extend the work performed under contract NAS 2-6147 to NASA Ames Research Center in which the basic method of predicting and optimizing shuttle trajectories based on sonic boom constraints was developed. Both contracts employed a pressure signature extrapolation technique and wind tunnel measurements developed by Ames Research Center.

The data base management system developed for the original contract and used extensively for two dimensional sonic boom prediction proved inadequate for the three-dimensional requirements of the present contract. A new data management system was developed which is versatile enough to handle present and future needs of the sonic boom methods employed.

The report is presented in two volumes:

Volume I Method and Results

Volume II Data Base Construction

The first volume describes the method employed for estimating ground overpressures from wind tunnel measurement. Some results are presented and the use of the computer program is described. Volume II describes the data management system employed in the data base construction and maintenance. A separate computer program developed for this purpose is also described.

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PREDICTION OF SONIC BOOM FROM EXPERIMENTAL NEAR-FIELD
OVERPRESSURE DATA. VOLUME II - DATA BASE CONSTRUCTION.

BY C. R. Glatt, S. J. Reiners and D. S. Hague
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SUMMARY

A technique for the construction and maintenance of a data base of overpressure signatures measured in the wind tunnel and augmented by extrapolation techniques is presented. The method is in the form of a digital computer program which contains the following elements:

1. A data base of measured near-field pressure signatures obtained from wind tunnel tests of a shuttle-type vehicle.
2. A method of initially storing wind tunnel measured data by angle of attack, Mach number and roll angle. The distance from the model at which the data was measured may also be a variable.
3. A method of updating the data base by which new signatures may be added or existing ones deleted or replaced.
4. A method of extrapolating existing data base signatures in the Mach plane to provide reasonable estimates of signatures in other Mach planes.
5. A method of plotting all signatures which currently reside in the data base.

The technique is discussed in detail and the entire pressure signature data base is presented. A description of the computer program input and output is also provided.

INTRODUCTION

A sonic boom computer program, SBOOM described in Volume I of this report, and a pressure signature data base maintenance program GETTAB are presented. The prediction technique calculates far-field overpressure from near-field pressure signatures measured in the wind tunnel. The wind tunnel results generally form an incomplete matrix of data for use in trajectory calculations. Therefore, an auxiliary interpolation/extrapolation technique based on the geometric similarity of pressure signatures was developed for making use of the wind tunnel data.

Wind tunnel data for a space shuttle delta wing orbiter configuration has been digitized and stored as a pressure signature data base using a newly developed access and retrieval system which provides unlimited expansion as more signature data is required. A program, GETTAB described in this volume, has been written for the purpose of storing and maintaining measured pressure signatures in the data base. The program also performs certain mapping of known signatures into signatures for flight regions where data is unavailable. The data base is accessed by the SBOOM program and pressure signatures for input flight conditions can be estimated using the geometric similarity rule developed. The data base and procedure developed estimates pressure signatures in the flight regime:

Angle of Attack	($10 < \alpha < 45$)
Mach Number	($1.2 < M < 10$)
Roll Angle	($0 < \theta < 180$)

The flight regimes span the normal range expected during reentry but does not cover all conditions expected during launch. Other data is available at low and higher angle of attack but is so stratified that the usefulness in the present method is questionable. The model employed in the tests represents a reentry vehicle and does not account for exhaust plumes which are present during launch. Tests at Ames Research Center indicate that plume effects invalidate the use of the data under launch conditions unless a "plume factor" is employed. A research effort to generate launch data including plume effects is now underway at Ames. Therefore, no effort to account for plume effects is included in the present study.

PRESSURE SIGNATURE DATA BASE

The procedure for determining sonic boom overpressures on the ground produced by vehicles flying at supersonic speeds is to define the near-field pressure signatures and then to extrapolate these signatures to the far-field (ground). Experience has shown that the best estimates of ground overpressure can be obtained by resorting to experimental rather than theory to determine near-field pressure signatures.

The purpose for generating the sonic boom pressure signature data base is to collect the results of several wind tunnel experiments in which near-field pressure signatures are measured for a range of anticipated flight conditions. These experiments have been conducted for a delta-wing shuttle vehicle. The Mach numbers ranged from 1.2 to 10.2. The angles of attack and roll angles ranged from 0 to 60 degrees and 0 to 180 degrees respectively. Even though current booster and orbiter configurations may differ from the one being investigated, the pressure signatures for the shape being tested are reasonably representative of the ones of interest provided the angle of attack is not small. This is borne out of comparison of results of straight and delta wing shapes discussed in reference 1.

Models having the shape shown in figure 1 have been tested in the Ames 3.35 by 3.3 meter (11 by 11 foot) 2.74 by 2.13 meter (9 x 7 foot) and 2.44 by 2.13 meter (8 x 7 foot) wind tunnels, and the jet propulsion laboratory .508 meter (20 inch) supersonic and the 0.533 meter (21 inch) hypersonic wind tunnels. The various angles of attack and roll angles were obtained by rotating the model and sting assembly relative to the pressure measuring equipment. The models were mounted on a linear actuator which permitted them to be translated longitudinally in the wind tunnels relative to the fixed pressure measuring equipment. Flow field pressures were detected by two degree included angle conical static pressure probe mounted on the wind tunnel wall which was connected to a capacitance type pressure transducer. Measured near-field sonic boom overpressures are presented in reference 1. A summary of the test conditions which resulted are presented in figure 2.

The wind tunnel test results which are presented in terms of $Dp/p = F(Dx/l)$ are converted to digital form so that the pressure signatures can be used directly in the SBOOM computer program. To insure the validity of the data transcribed from graph to digital data, CALCOMP plots of the digitalized data were generated using an independent plotting program. These plots were drawn to the exact scale of those presented in reference 1. They were carefully compared with the original plots by overlaying one

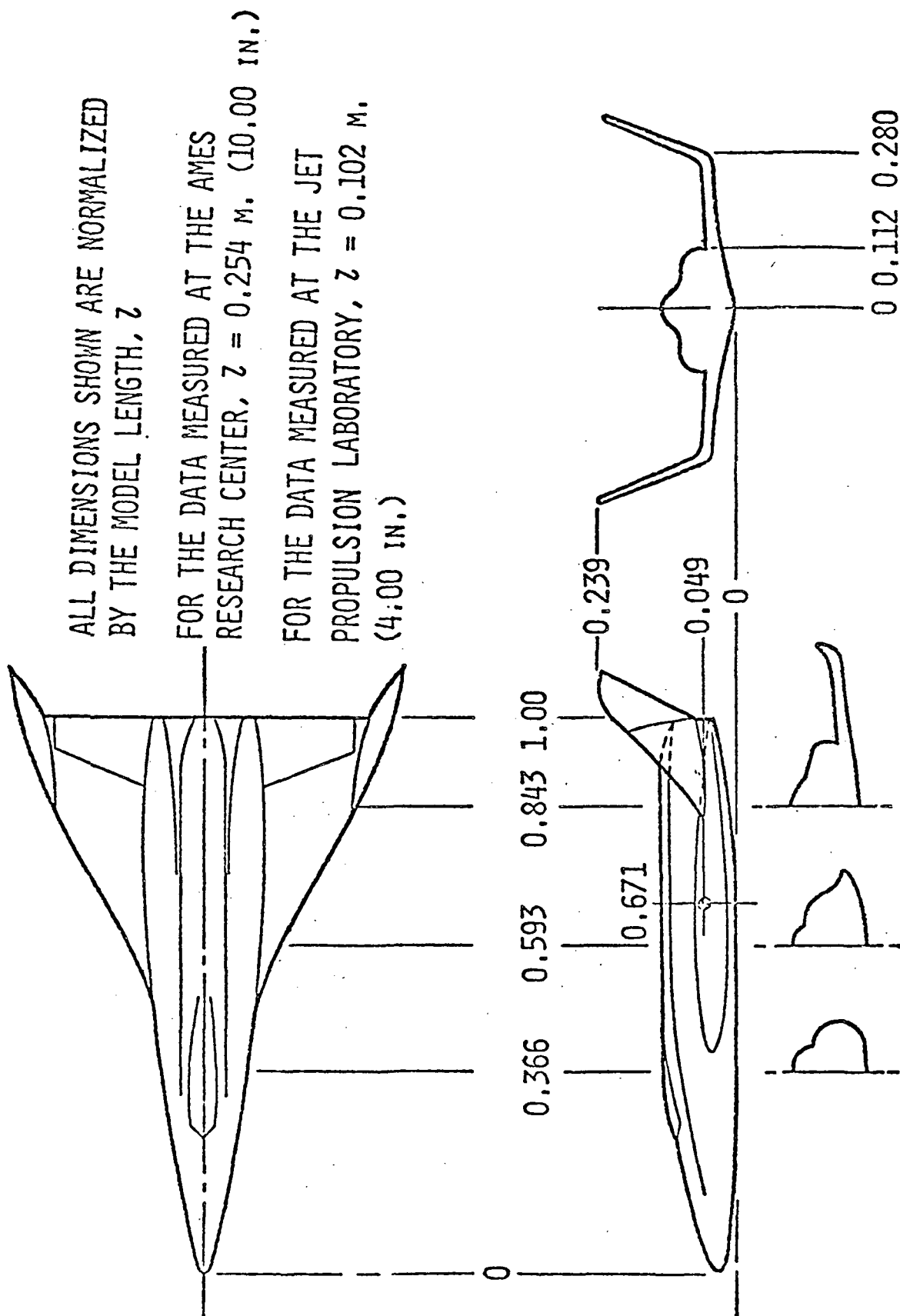
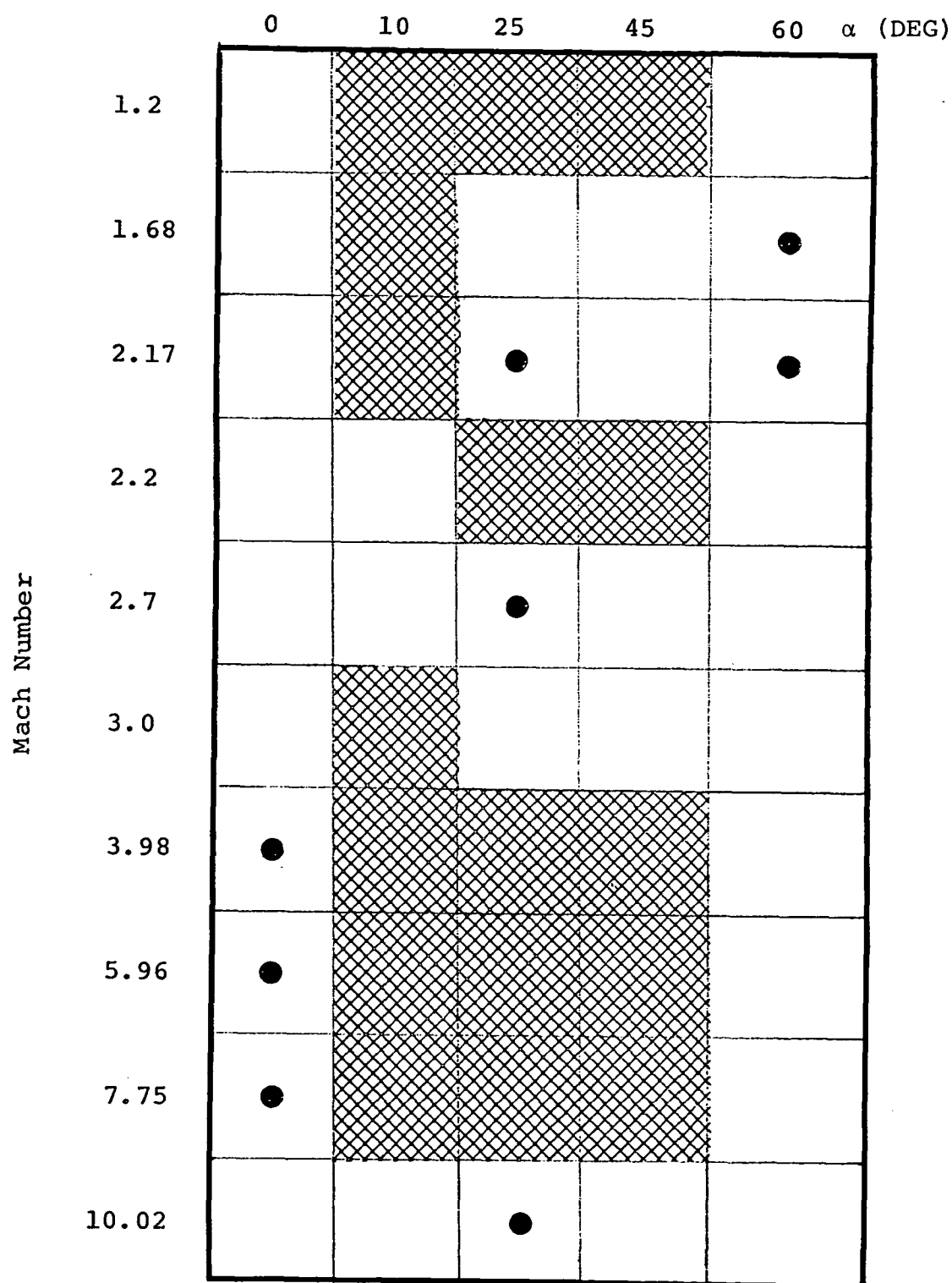


FIGURE 1 MODEL SKETCH



LEGEND:



Full Roll Angle Range



Data at Zero Roll Angle Only

FIGURE 2 MEASURED SONIC BOOM PRESSURE SIGNATURES.

on the other. All signatures which have been digitized are presented in Appendix A. (not necessarily to the same scale as the original overlays)

After the comparison of the digitalized data with the wind tunnel results, the data was transferred directly into the pressure signature data base using the auxiliary storage and retrieval program GETTAB described in this report. Only selected data has been actually stored in the pressure signature data base at this time. These data are available on data cell and may be used by simply attaching the proper file when executing the SBOOM program (see Volume I).

Extrapolation

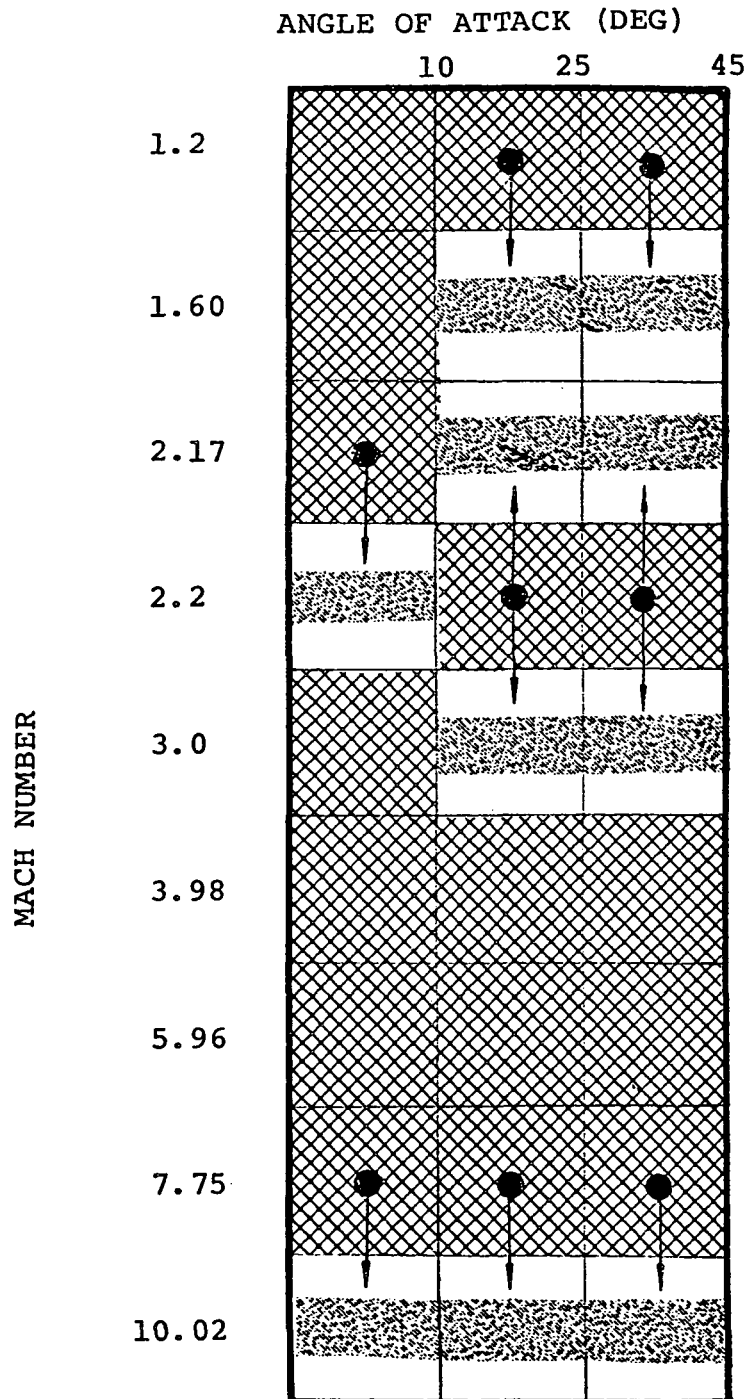
The use of stratified data represented by the wind tunnel test conditions required the development of some extrapolation procedures. Since data is not always available at the desired test conditions, a polynomial extrapolation technique was developed for generating pressure signatures outside the range of the test data. The technique developed used the input stations ($\Delta\chi/\ell$) of the given curve and scales the $\Delta P/P$ values of the given curve by the following factor:

$$(M1/M2)^k$$

where $M1$ is the Mach number of the given curve, $M2$ is the Mach number of the desired curve, and k is a constant equal to 2 for extrapolating high Mach number signatures to higher Mach numbers and 1.5 for extrapolating low Mach number signatures to lower Mach numbers.

Tests of the extrapolation technique included extrapolation of given experimental data base signatures for other data base experimental curves (see Volume I). Results of these curves showed the extrapolation technique used was quite accurate in the Mach plane. No methods have been developed for extrapolating in the angle of attack or roll angle planes.

The extrapolation procedures developed were used to produce an enriched near-field data base of signatures. In this way, all near-field experimental signatures used during a trajectory analysis result from interpolations of data base signatures. Figure 2 illustrates the flight conditions for which wind tunnel measurements of pressure signatures were available. Low and high angle of attack data was very sparse so were omitted from the final data base. Mach 2.7 was omitted because the extrapolation method for augmenting this data produces the less reliable results than those obtained from interpolation in the SBOOM program. The flight conditions stored in the final data base are shown in figure 3.



LEGEND:

- XXXXXX Actual Recorded Signatures.
- Extrapolated Signatures.
- ↓ ↑ Source of Extrapolated Values.

FIGURE 3 AUGMENTED SONIC BOOM PRESSURE SIGNATURE DATA BASE DEFINITION.

Estimations of pressure signatures outside this region will generate the boundary signature. The arrows in figure 3 indicate the source of the data for the pressure signature augmentations.

Data Management

The storage and retrieval of the pressure signature data employs a rapid access name oriented system which eliminates the serial file search ordinarily associated with data retrieval. The data management scheme augments the CDC 6000 series "random access" technique by maintaining a directory of file locations where the data base information is stored. The stored information includes:

1. The pressure signatures.
2. A list of roll angles for which data is available.
3. A list of Mach numbers for which data is available.
4. A list of angles of attack for which data is stored.
5. A directory to the above information.

The pressure signatures include alternating values of DP/P and Dx/l in point pairs, the number of point pairs and the corresponding h/l values for the signature. Items 2, 3 and 4 provide the range of data which are checked by the SBOOM program (Volume I) when interpolations are performed. Data base requests outside the range of stored data result in the use of the boundary signature "nearest" the required signature.

The directory is stored in a separate file by the data management system but is read into core at the beginning of program execution. Upon request for a particular signature, the directory is searched for data base locations where the actual data is stored. The addressing function used for the directory search is:

$$\begin{aligned} \text{ADDRESS} &= \text{I. P. } (\text{ALPHA} * 10) * 10^5 \\ &+ \text{I. P. } (M * 100) * 10 \\ &+ \text{I. P. } (\text{PHI} * 10) \end{aligned}$$

Where: I. P. means INTEGER PART

ALPHA = Angle of Attack

M = Mach Number

PHI - Roll Angle

The accuracy of the data base parameters implied by the above addressing function is as follows:

ALPHA = 0.05 Degrees.

Mach = 0.005.

PHI = 0.05 Degrees.

The data management system permits automatic expansion of the data through replacement of existing data or addition of new data. Data may be deleted by individual signature of entire Mach and Alpha planes may be removed.

GETTAB PROGRAM USAGE

The program GETTAB is used for the purpose of initially storing or modifying the data base of pressure signatures. GETTAB uniquely names each signature based on the numerical values of the associated Mach number, angle of attack and roll angle by the addressing function described above. The signature is stored by the composite name and later retrieved by the same name in SBOOM. To initially construct the data base of near-field pressure signatures, each signature is digitized as alternating values of DX/1 and DP/P values.

Namelist Data Format

The program uses NAMELIST input for the following reasons:

1. It is a simple name oriented input easily understood by most engineers.
2. The format is standard and does not require relearning from program to program.
3. It is easily modified by the engineer or programmer when adding input variables to the program.

When NAMELIST read is encountered in a program, the entire input file is scanned up to an end-of-file or a record with a \$ in column 2 followed immediately by the namelist name requested by the program. Succeeding data items are read until a second \$ is

encountered signifying the end of the NAMELIST. Any data on the input file before the requested namelist is found will be ignored. All data between the opening and closing \$ are interpreted by NAMELIST. The data item within the NAMELIST statement may be in any of three forms:

$$v = c,$$
$$a = d_1, \dots, d_j,$$
$$a(n) = d_1, \dots, d_m,$$

v is a variable name; c is a constant; a is an array name and n is an integer constant subscript, d₁ are simple constants or repeated constants of the form k*c, where k is the repetition factor. Data items and constants must be separated by commas.

The number of constants, including repetitions, given for an unsubscripted array name must equal the number of elements in that array. For a subscripted array name, the number of constants need not equal, but may not exceed, the number of array elements needed to fill the array.

The specified constant of the NAMELIST statement may be integer, real, double precision, complex of the form (c₁,c₂) or logical of the form T, or .TRUE., F, or .FALSE.. A logical or complex variable may be set only to a logical and complex constant, respectively. Any other variable may be set to an integer, real or double precision constant. Such a constant is converted to the type of its associated variable.

Constants and repeated constant fields may not include embedded blanks. Blanks, however, may appear elsewhere in data records.

The entire card record excluding the first character is permitted. More than one card may be used for input data, and arrays may be split between cards. All except the last record must end with a constant followed by a comma, and no sequence numbers may appear. The first column of each record is ignored.

Input Description

The signatures are stacked in separate cases for the program GETTAB. A description of the required input is shown in figure 4. The Sonic Boom pressure signature data base is stored on TAPE10. This data should be saved as a tape or a data cell file for later use

<u>NAMelist</u> <u>NAME</u>	<u>NOMINAL</u> <u>VALUES</u>	<u>DESCRIPTION</u>
ALF	0.	Floating point number specifying the angle of attack (degrees) for this near-field pressure signature.
DELALF*	.FALSE.	If .TRUE., program deletes all signatures identified by the specified angle of attack (ALF) for all Mach numbers and all roll angles.
DELETE*	.FALSE.	If .TRUE., program deletes one specified (by ALF, XMAC, PHI) signature for the data base. Not required if replacing an existing signature.
DELMAC*	.FALSE.	If .TRUE., program deletes all signature identified by the specified Mach number (XMAC) for all angles of attack and all roll angles.
EOFILe	.FALSE.	Logical variable input .TRUE. after last signature is input. Default value = .FALSE. Note: System end-of-file (7-8-9) also recognized as input termination.
EXTFRM	0.	Floating point value specifying that a Mach number extrapolation from the signature identified by ALF and EXTFRM to ALF and XMAC be performed. The resulting signature is stored in the data base. Note: This is reset after each case.
HL1	0.	Floating point number specifying the h/l value associated with this signature.
N1	0.	An integer specifying the number of points (pairs of DX/l, DP/P values) in this signature.
PHI	0.	Floating point number specifying roll angle (degrees) for this near-field signature.

FIGURE 4A NAMelist \$IN INPUT.

<u>NAMELIST NAME</u>	<u>NOMINAL VALUES</u>	<u>DESCRIPTION</u>
PLOT	.FALSE.	If .TRUE., input file is generated for the independent plot program to plot pressure signatures for entire data base.
PRINTA	.FALSE.	If .TRUE., list the complete data base.
TB1	0.	An array of floating point values for this signature, ordered as follows: $DX/l_1, DP/P_1, DX/l_2, DP/P_2, \dots, -DX/l_{NI}, DP/P_{NI}$ where the first point ($DX/l_1, DP/P_1$) is the first significant pressure value in the signature.
XMAC XMACH	0.	Floating point number specifying the Mach number for this signature.

*Deletion of data base information is only necessary when voiding portions of the data base. The program has automatic overwrite capability when replacing existing signatures. All delete functions are reset to .FALSE. after each case.

FIGURE 4B NAMELIST \$IN INPUT. (CONTINUED)

by the SBOOM program. Figure 5 is an example of a typical data deck to initially build and/or modify the near-field pressure signature data base. An example of changing a signature already stored in the data base is illustrated as the last case in figure 5.

Deck Setup

The deck setup for the creation or update of the pressure signature data base is shown in figure 6. The deck setup employs a modified version of the LRC system FETCH program. The use of this version of FETCH eliminates the necessity of specifying the "wedge number" on subsequent FETCH executions. The GETTAB program is stored as an absolute element program so the name used must be OGET.

Tape 10 is the unit identification for the storage location of the pressure signature data base. If the run is a data base creation run, the DROPFIL card must be present. If the run is an update of an existing data base, the DROPFIL card must be omitted. Source input for the pressure signatures and the GETTAB program are stored on the following data cells:

GETTAB Program	DA397
----------------	-------

Pressure Signatures	DA420
---------------------	-------

	\$IN	
	ALF = 0.,	(all signatures correspond to zero angle of attack until the value ALF is again input.)
Input for	{ XMAC = X,	(The Mach number for this signature.)
First	{ HLI = X,	(The h/l value for this signature.)
Signature	{ PHI = X,	(Roll angle for this sig.)
	{ N1 = n,	(The number of points in this signature.)
	TB1 = DX/l ₁ , DP/P ₁ ,	(The data points on this pressure signature.)
	DX/l ₂ , DP/P ₂ ,	
	\$	
Input for	{ \$IN	
Second	{ XMAC = X,	(The Mach number for this signature.)
Signature	{ HLI = X,	(The h/l value for this sig.)
	{ N1 = n,	(The number of points on this signature.)
	TB1 = DX/l ₁ , DP/P ₁ ,	(The data points for this pressure signature.)
	\$	
	.	
	.	
	.	
	.	
	.	
	.	
Input for	{ \$IN	
Last	{ XMAC = X,	(The Mach number for this last signature.)
Signature	{ EXTFRM = Y,	(Mach number from which extrapolation occurs.)
	\$	
Signifies	{ \$IN	
End of	{ EOFILE = .TRUE.,	
Input	{ \$	

NOTE: NAMELIST variable values which are unchanged from case to case need not be input.

FIGURE 5 ILLUSTRATION OF INITIAL STORAGE OF THE SONIC BOOM DATA BASE.

```

RUN,1,10,40000,500.
USER - - -
FETCH,A3682,SPRZ14,BINARY,,FETCH.
FETCH,A4197,,BINARY,,OGET.

FETCH,DA423,,DATA,,,TAPE10.
DROPFIL,TAPE10,*
OGET.

REWIND,TAPE10.
REPLACE,TAPE10,,,,,LABEL.
7-8-9
        DATA FOR NEW DATA BASE OR
        MODIFICATION OF OLD ONE
7-8-9
        DATA CELL LABEL
6-7-8-9
        *REQUIRED IF AND ONLY IF THIS
        IS A NEW DATA BASE.

```

FIGURE 6 DECK SETUP FOR GETTAB.

REFERENCES

1. Hicks, Raymond M. and Mendoza, Joel P.: Wind Tunnel Pressure Signatures for Delta Wing Space Shuttle Fuel Tank, NASA TM X-62, 119, SSPD-80, April 1972.

APPENDIX A - SONIC BOOM PRESSURE SIGNATURE DATA BASE

TABLE A-1 INDEX TO PRESSURE SIGNATURE PLOTS

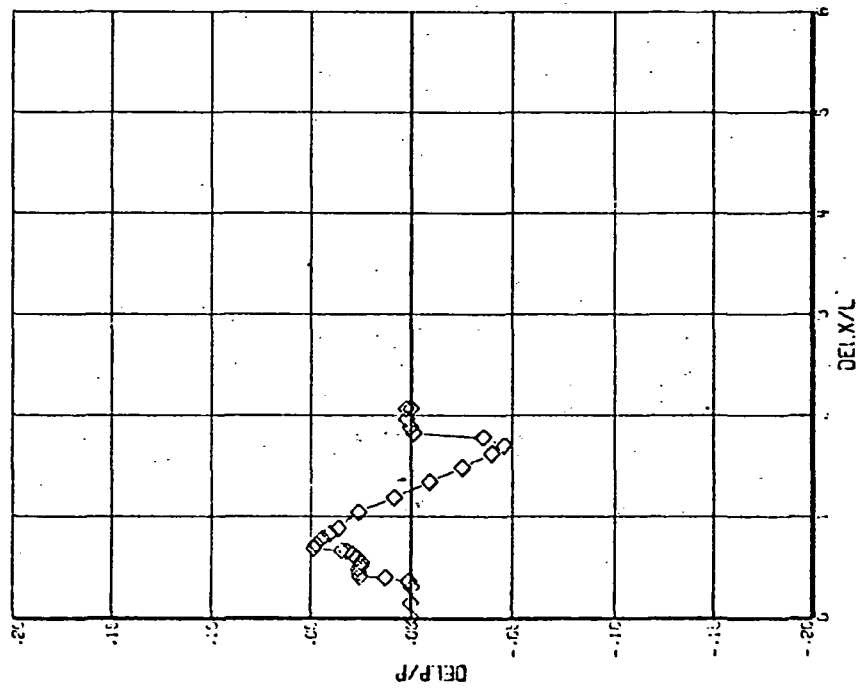
MACH	ALPHA	PHI	PLOT	MACH	ALPHA	PHI	PLOT
1.20	10.00	0.0	1	2.20	45.00	143.2	41
1.20	10.00	30.0	2	2.20	45.00	180.0	42
1.20	10.00	60.0	3	2.70	25.00	0.0	43
1.20	25.00	0.0	4	2.70	60.00	0.0	44
1.20	25.00	27.2	5	3.00	10.00	0.0	45
1.20	25.00	83.8	6	3.00	10.00	28.1	46
1.20	25.00	114.3	7	3.00	10.00	56.7	47
1.20	25.00	146.6	8	3.00	10.00	86.1	48
1.20	25.00	180.0	9	3.00	10.00	116.7	49
1.20	45.00	0.0	10	3.00	10.00	148.0	50
1.20	45.00	25.5	11	3.00	10.00	180.0	51
1.20	45.00	51.8	12	3.98	0.00	0.0	52
1.20	45.00	79.7	13	3.98	10.00	0.0	53
1.20	45.00	110.2	14	3.98	10.00	28.1	54
1.20	45.00	143.9	15	3.98	10.00	56.7	55
1.20	45.00	180.0	16	3.98	10.00	86.1	56
1.68	10.00	0.0	17	3.98	10.00	116.5	57
1.68	10.00	30.0	18	3.98	10.00	148.0	58
1.68	10.00	60.0	19	3.98	10.00	180.0	59
1.68	10.00	90.0	20	3.98	25.00	0.0	60
1.68	25.00	0.0	21	3.98	25.00	25.8	61
1.68	60.00	0.0	22	3.98	25.00	52.3	62
2.17	10.00	0.0	23	3.98	25.00	80.6	63
2.17	10.00	30.0	24	3.98	25.00	111.1	64
2.17	10.00	60.0	25	3.98	25.00	144.6	65
2.17	10.00	90.0	26	3.98	25.00	180.0	66
2.17	25.00	0.0	27	3.98	45.00	0.0	67
2.17	60.00	0.0	28	3.98	45.00	23.5	68
2.20	25.00	0.0	29	3.98	45.00	47.9	69
2.20	25.00	25.8	30	3.98	45.00	74.6	70
2.20	25.00	52.3	31	3.98	45.00	109.1	71
2.20	25.00	80.7	32	3.98	45.00	143.2	72
2.20	25.00	111.2	33	3.98	45.00	180.0	73
2.20	25.00	144.6	34	5.96	0.00	0.0	74
2.20	25.00	180.0	35	5.96	10.00	0.0	75
2.20	45.00	0.0	36	5.96	10.00	27.8	76
2.20	45.00	25.1	37	5.96	10.00	56.1	77
2.20	45.00	51.0	38	5.96	10.00	85.2	78
2.20	45.00	78.9	39	5.96	10.00	115.8	79
2.20	45.00	109.3	40	5.96	10.00	147.6	80

TABLE A-1 (CONTINUED) INDEX TO PRESSURE SIGNATURE PLOTS

MACH	ALPHA	PHI	PLOT
5.96	10.00	180.0	81
5.96	25.00	0.0	82
5.96	25.00	25.1	83
5.96	25.00	51.1	84
5.96	25.00	78.6	85
5.96	25.00	109.5	86
5.96	25.00	143.5	87
5.96	25.00	180.0	88
5.96	45.00	0.0	89
5.96	45.00	22.4	90
5.96	45.00	45.5	91
5.96	45.00	70.8	92
5.96	45.00	100.4	93
5.96	45.00	134.9	94
5.96	45.00	180.0	95
7.75	0.00	0.0	96
7.75	10.00	0.0	97
7.75	10.00	27.7	98
7.75	10.00	56.2	99
7.75	10.00	85.7	100
7.75	10.00	116.4	101
7.75	10.00	147.9	102
7.75	10.00	180.0	103
7.75	25.00	0.0	104
7.75	25.00	25.9	105
7.75	25.00	52.5	106
7.75	25.00	80.9	107
7.75	25.00	111.4	108
7.75	25.00	144.7	109
7.75	25.00	180.0	110
7.75	45.00	0.0	111
7.75	45.00	23.6	112
7.75	45.00	48.0	113
7.75	45.00	74.6	114
7.75	45.00	104.6	115
7.75	45.00	139.8	116
7.75	45.00	180.0	117
10.02	25.00	0.0	118

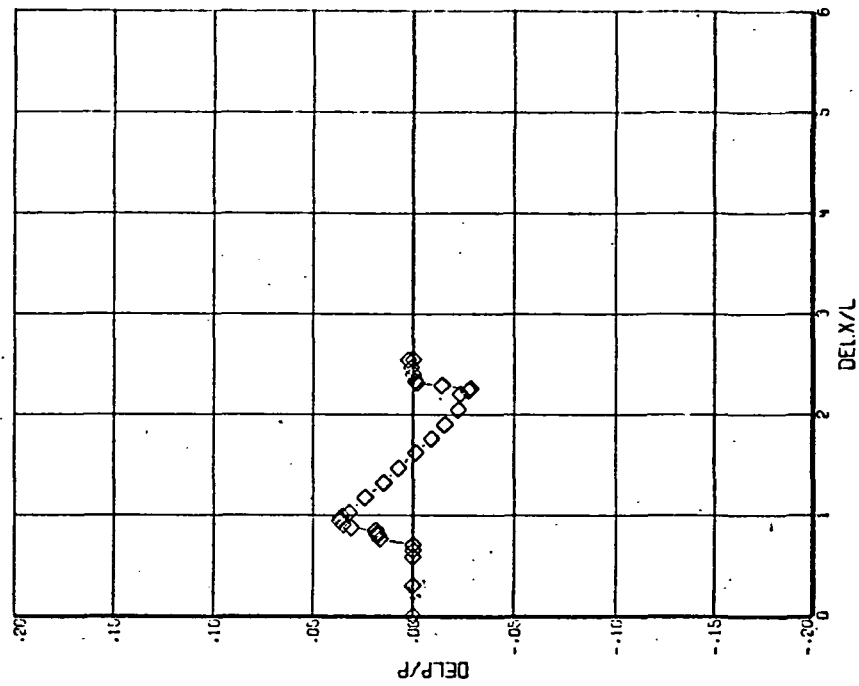
$\text{MACH} = 1.200$ $\text{ALPHA} = 10.000$ $\text{PHI} = 0.000$ $\text{H/L} = 2.7000$

PLOT 1



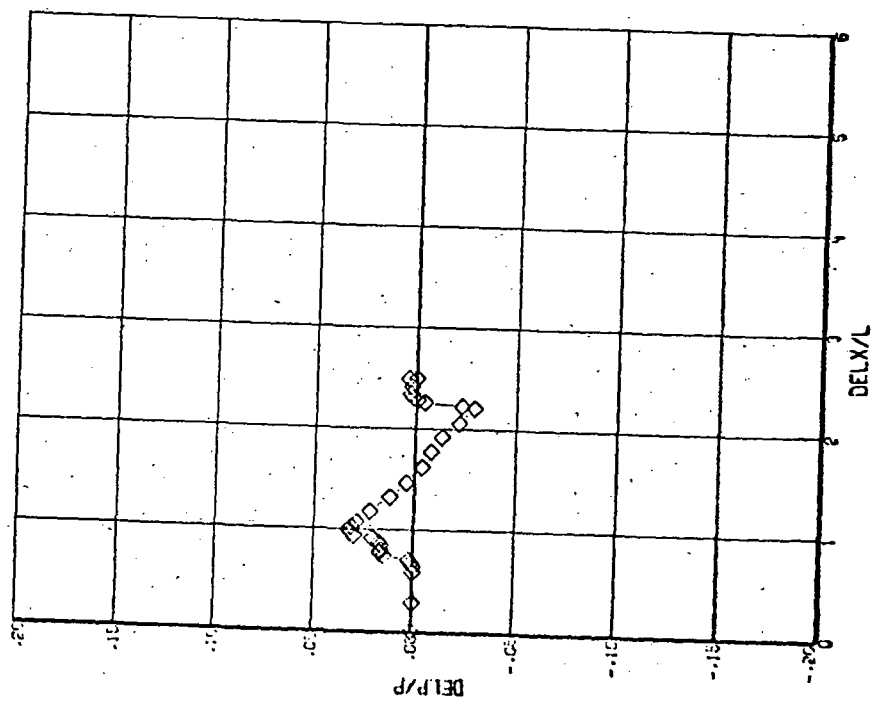
$\text{MACH} = 1.200$ $\text{ALPHA} = 10.000$ $\text{PHI} = 30.000$ $\text{H/L} = 5.3000$

PLOT 2



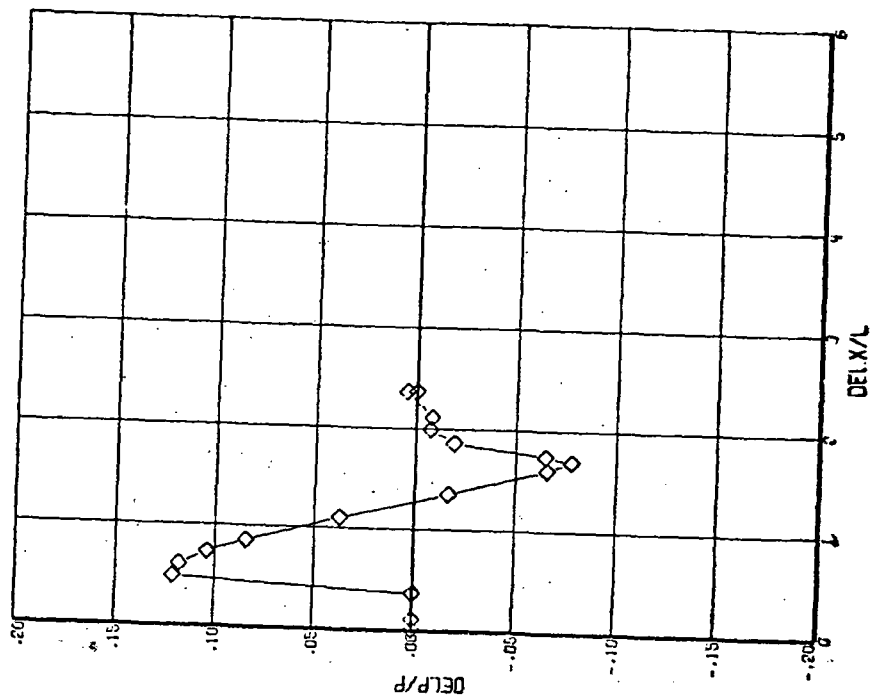
$\mu_{CH} = 1.200$ $\alpha_{PHR} = 10.000$ $\phi_H = 60.000$ $N/L = 5.3000$

PLOT 3



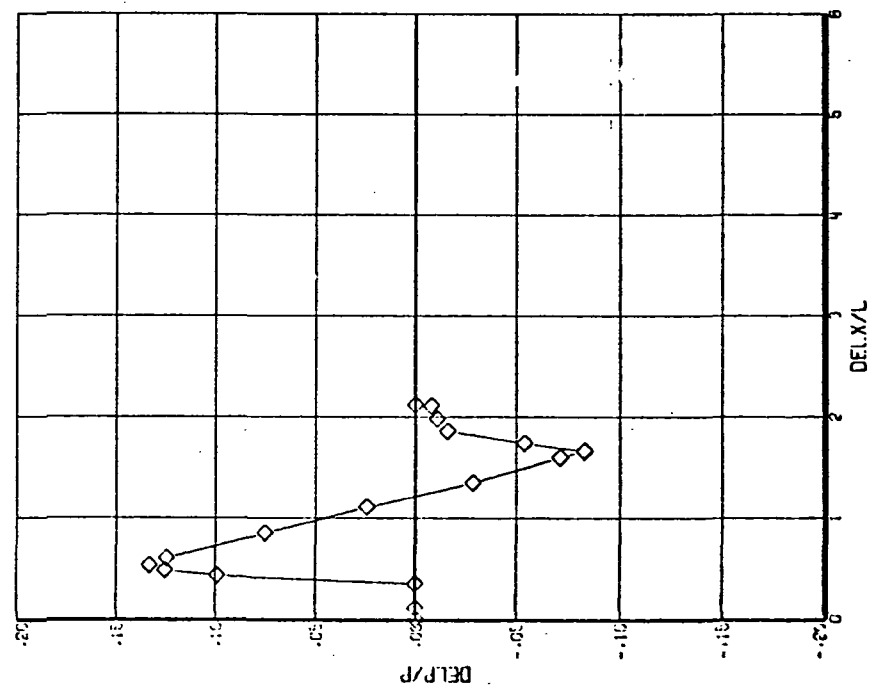
$\mu_{CH} = 1.200$ $\alpha_{PHR} = 25.000$ $\phi_H = 0.000$ $N/L = 2.1600$

PLOT 4



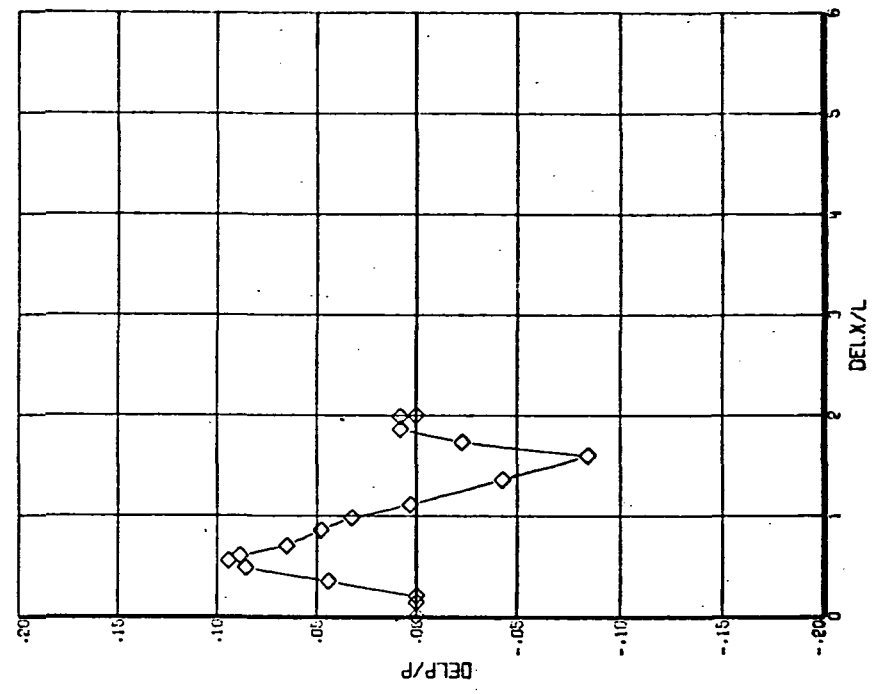
MSCH = 1.200 ALPHA = 25.000 PHI = 27.200 H/L = 2.1300

PLOT 5



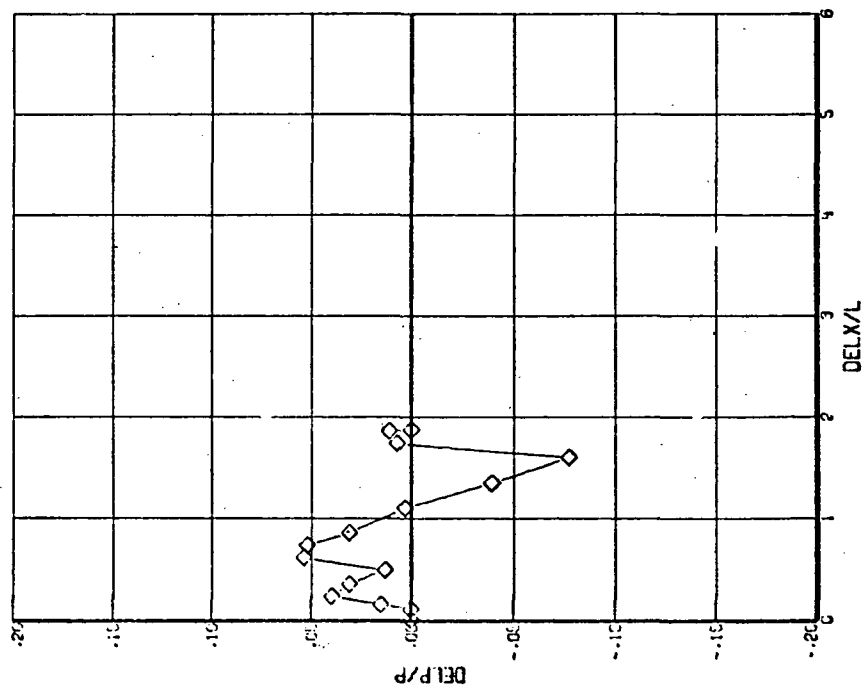
MSCH = 1.200 ALPHA = 25.000 PHI = 83.900 H/L = 1.9500

PLOT 6



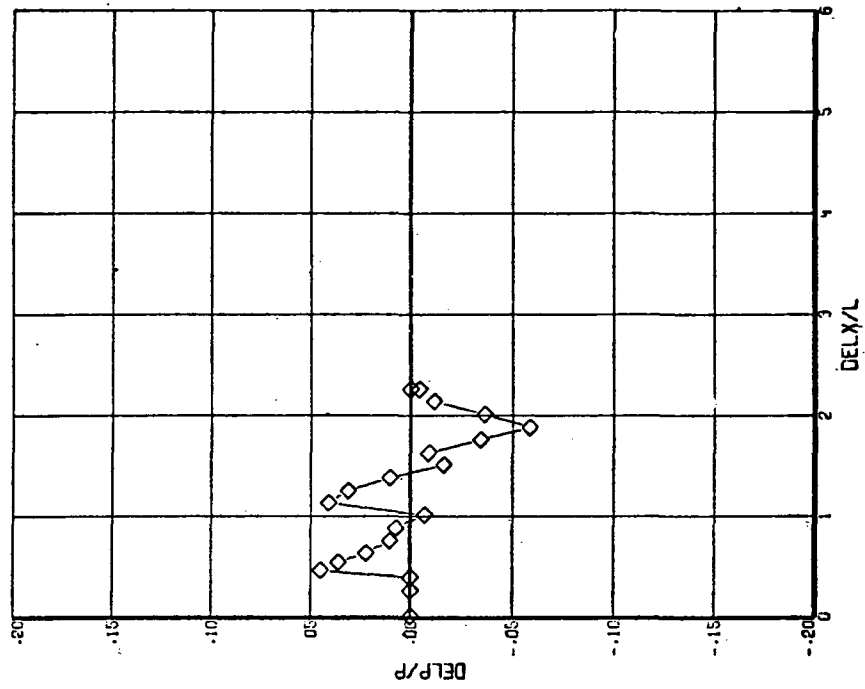
MECH = 1.200 ALPHA = 25.000 PHI = 114.300 M/L = 1.8000

PLOT 7



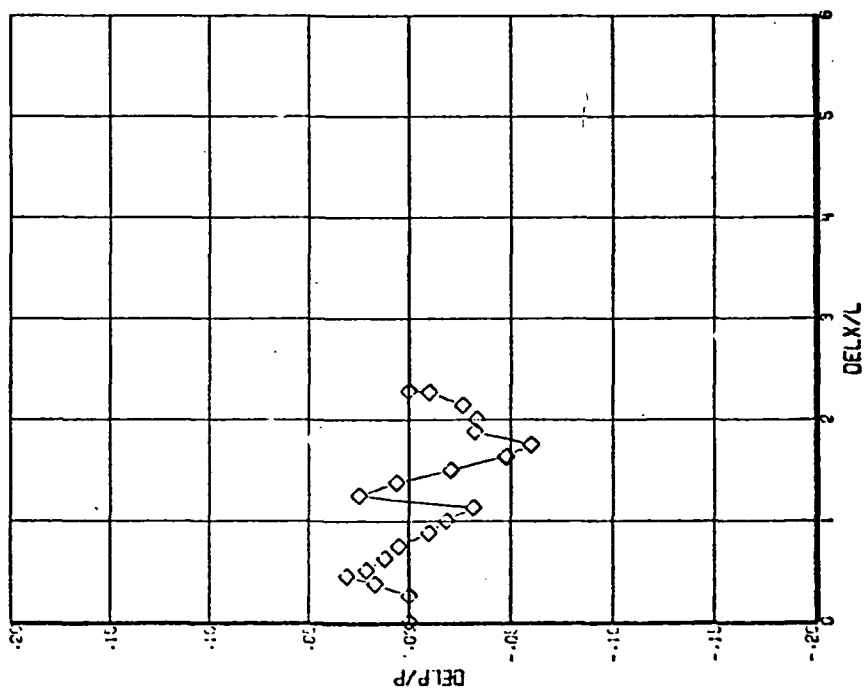
MECH = 1.200 ALPHA = 25.000 PHI = 146.600 M/L = 1.7700

PLOT 8



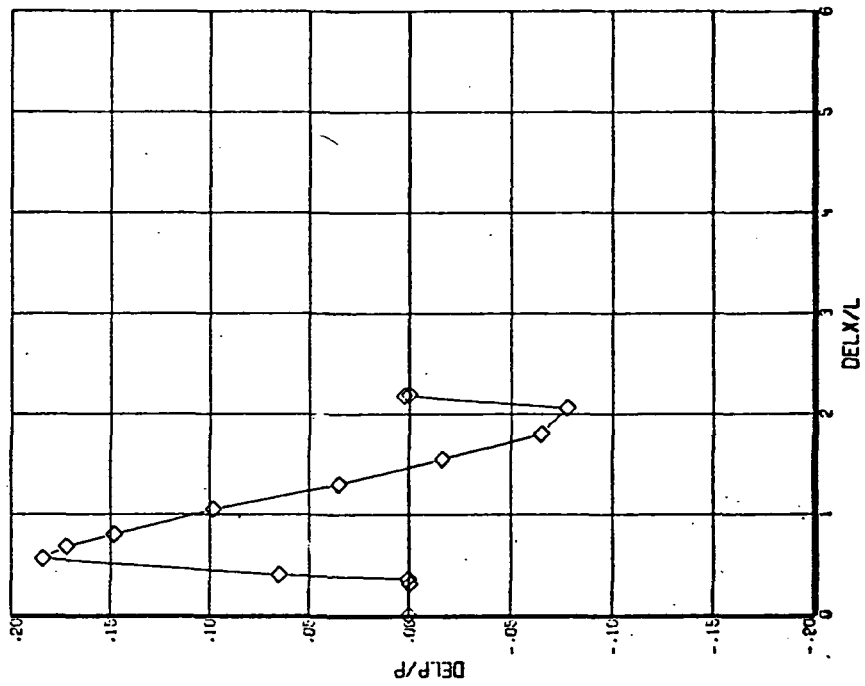
$\mu_{CH} = 1.200$ $\alpha_{PH} = 26.000$ $\phi_H = 180.000$ $M/L = 1.7100$

PLOT 9



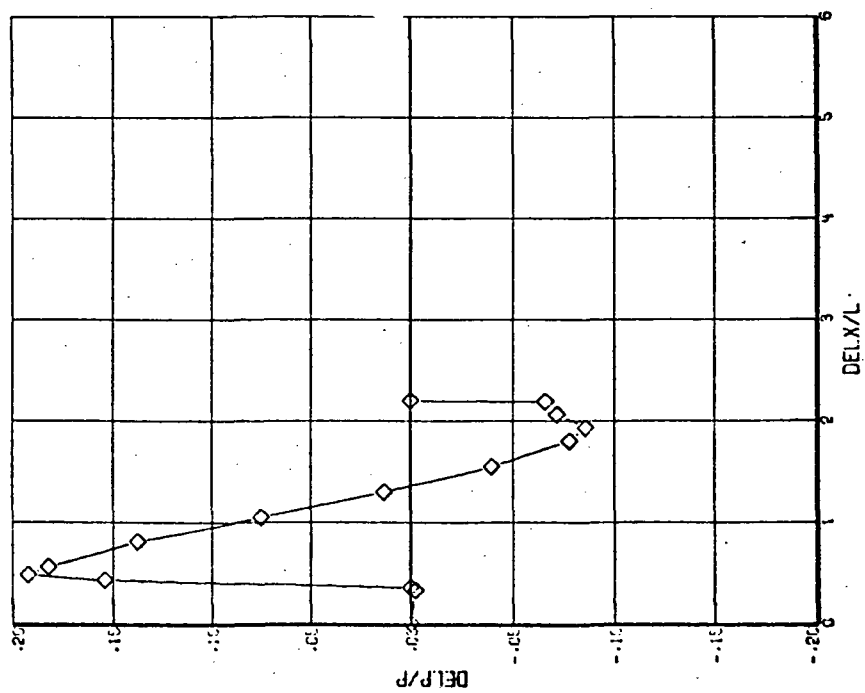
$\mu_{CH} = 1.000$ $\alpha_{PH} = 45.000$ $\phi_H = 0.000$ $M/L = 2.3000$

PLOT 10



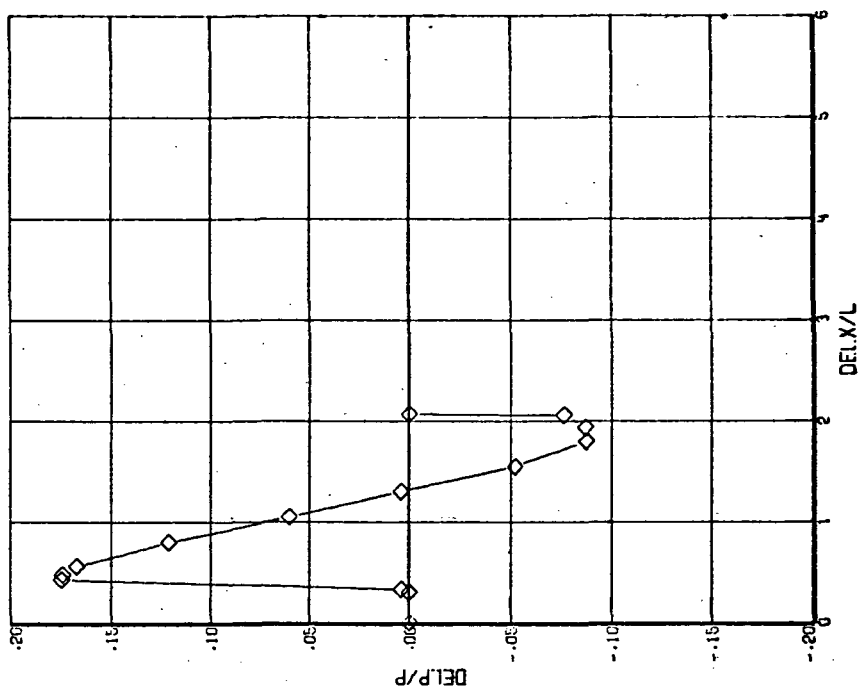
MECH = 1.200 ALPHA = 45.000 PHI = 25.500 H/L = 2.2600

PLOT 11



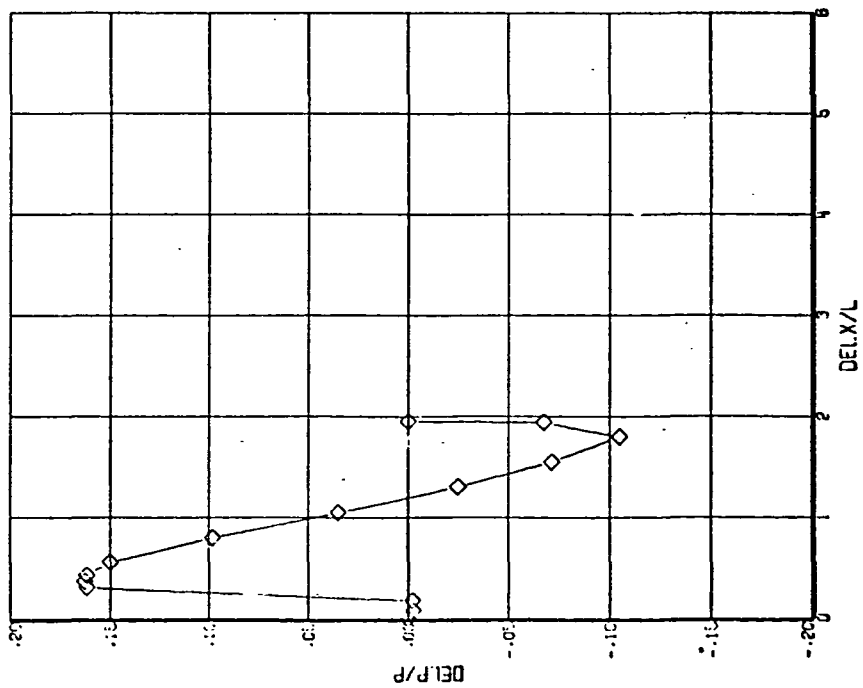
MECH = 1.200 ALPHA = 45.000 PHI = 51.800 H/L = 2.1000

PLOT 12



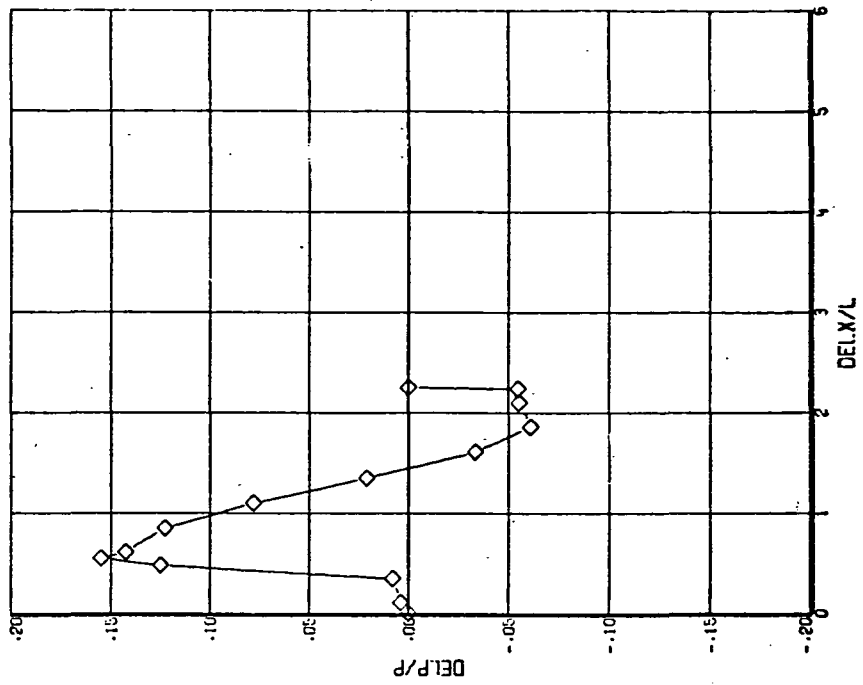
MSCH = 1.200 ALPHA = 45.000 PHI = 79.700 W/L = 1.3900

PLOT 13



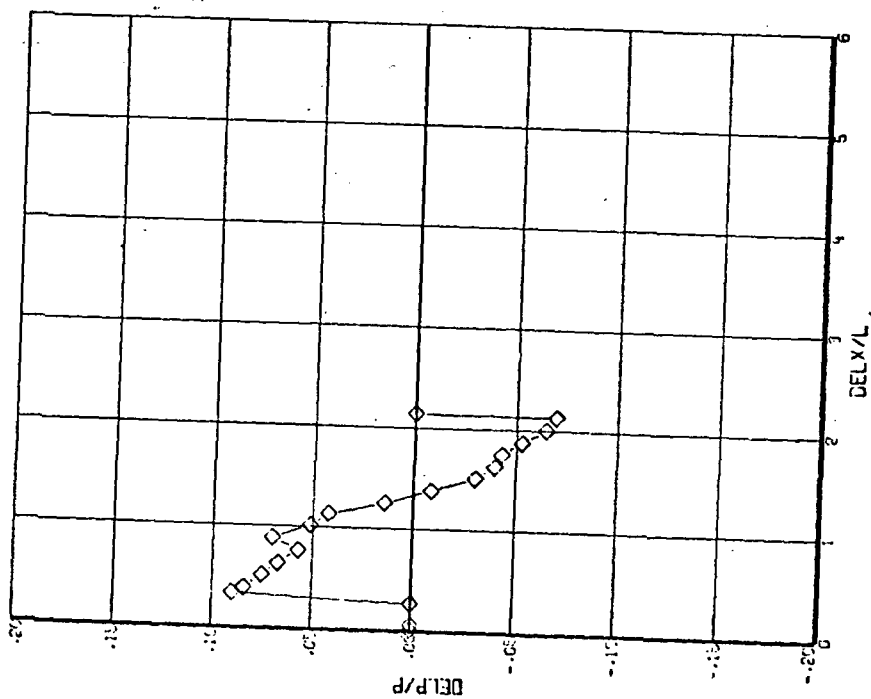
MSCH = 1.200 ALPHA = 45.000 PHI = 110.200 W/L = 1.9000

PLOT 14



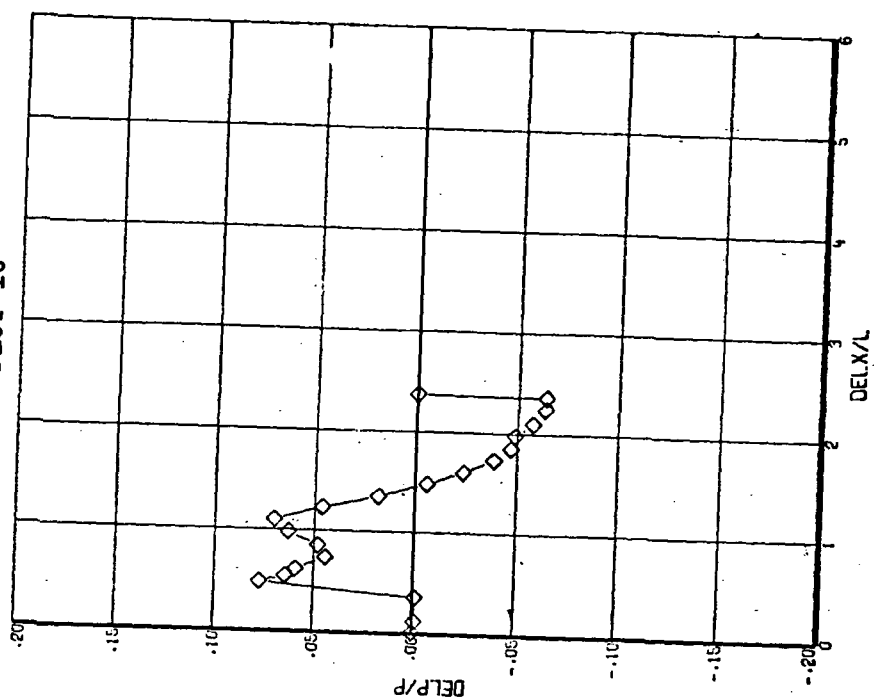
MECH = 1.200 ALPHA = 45.000 PHI = 143.300 H/L = 1.6500

PLOT 15



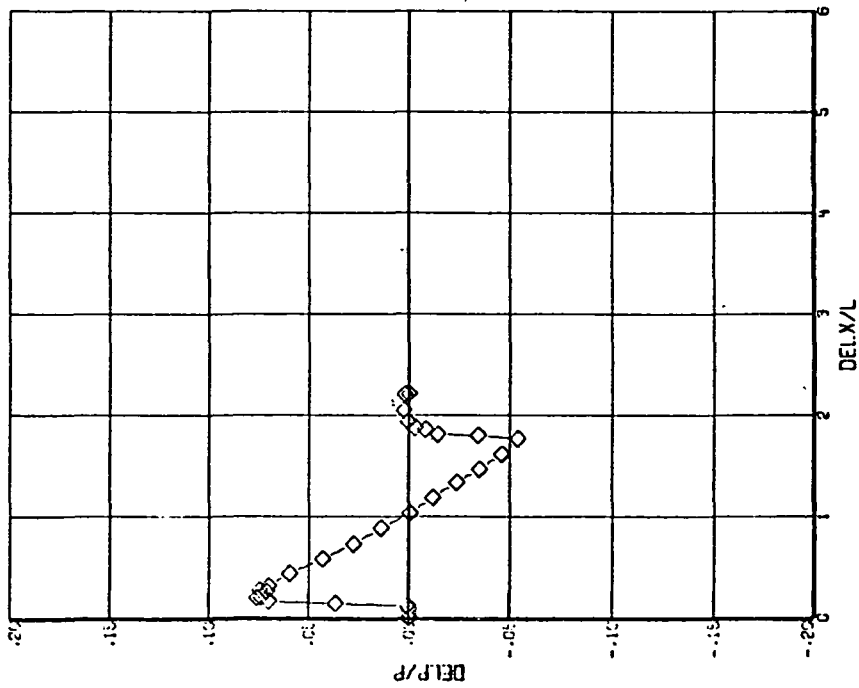
MECH = 1.200 ALPHA = 45.000 PHI = 180.000 H/L = 1.6000

PLOT 16



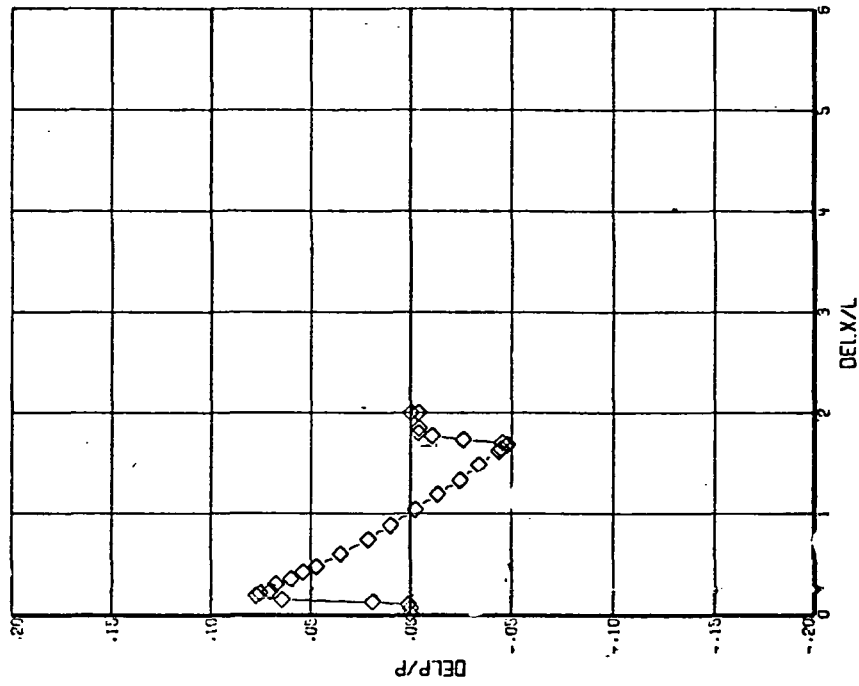
$\mu_{SCH} = 1.690$ $\mu_{PMA} = 10.000$ $\mu_{H1} = 0.000$ $M/L = 4.0590$

PLOT 17



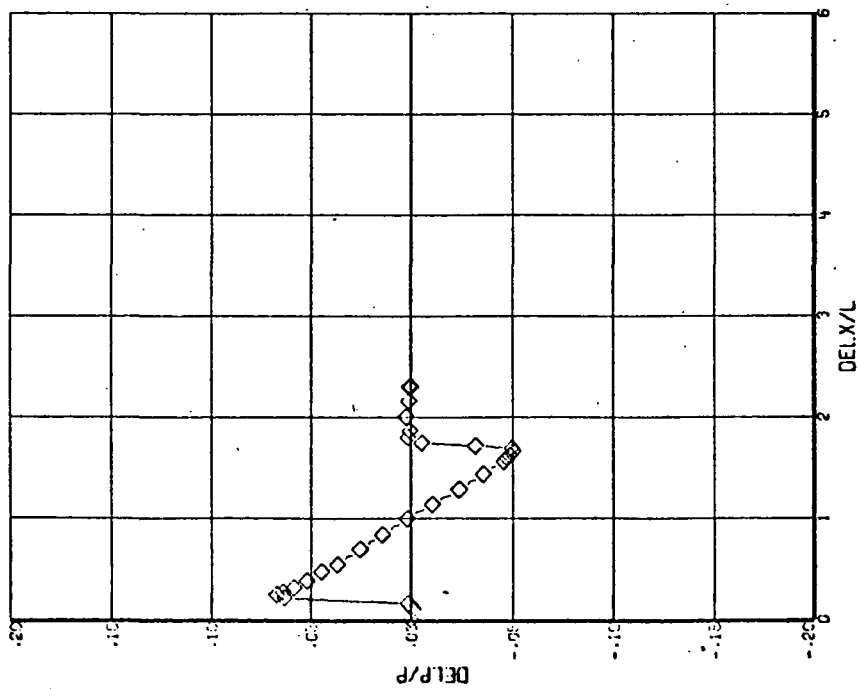
$\mu_{SCH} = 1.680$ $\mu_{PMA} = 10.000$ $\mu_{H1} = 30.000$ $M/L = 4.0390$

PLOT 18



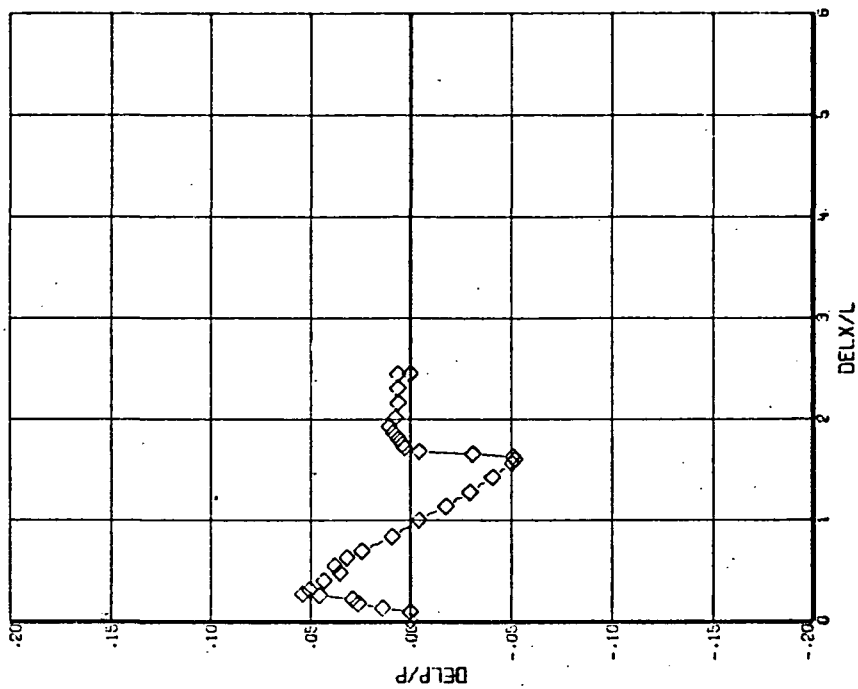
MOCH = 1.690 ALPHA = 10.000 PHI = 60.000 W/L = 4.0330

PLOT 19



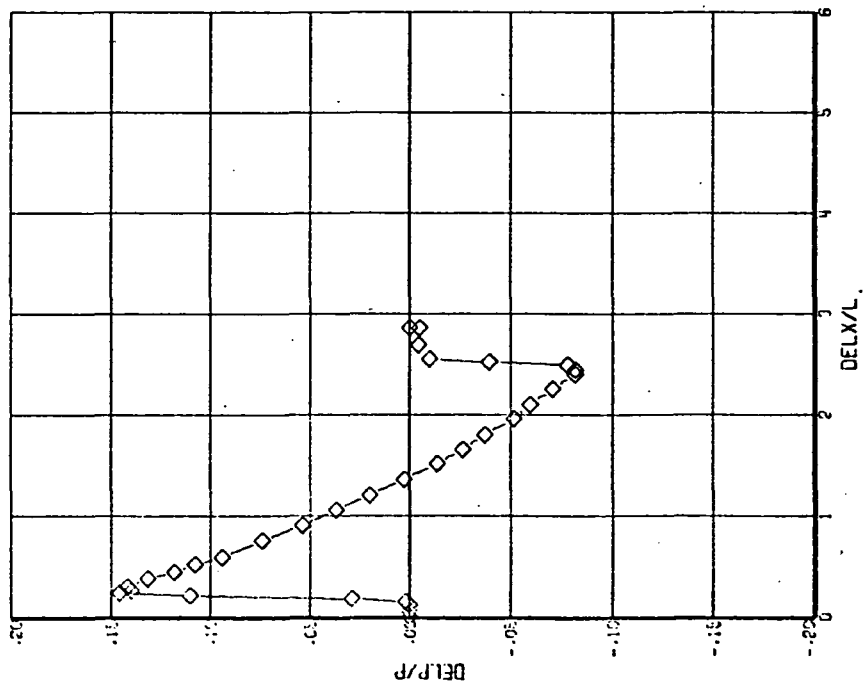
MOCH = 1.690 ALPHA = 10.000 PHI = 90.000 W/L = 4.0330

PLOT 20



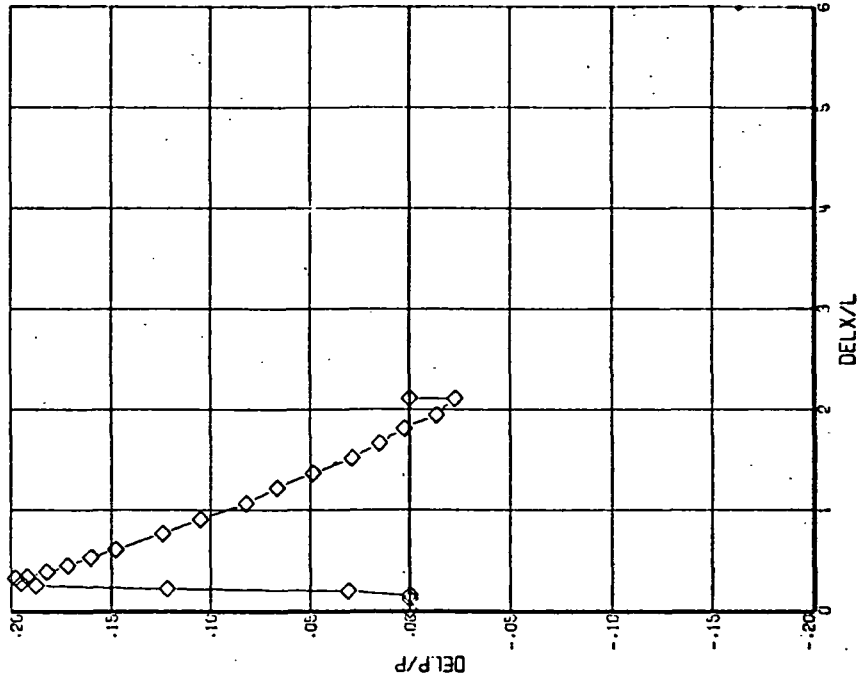
MECH = 1.990 ALPHA = 25.000 PHI = 0.000 W/L = 3.9120

PLOT 21



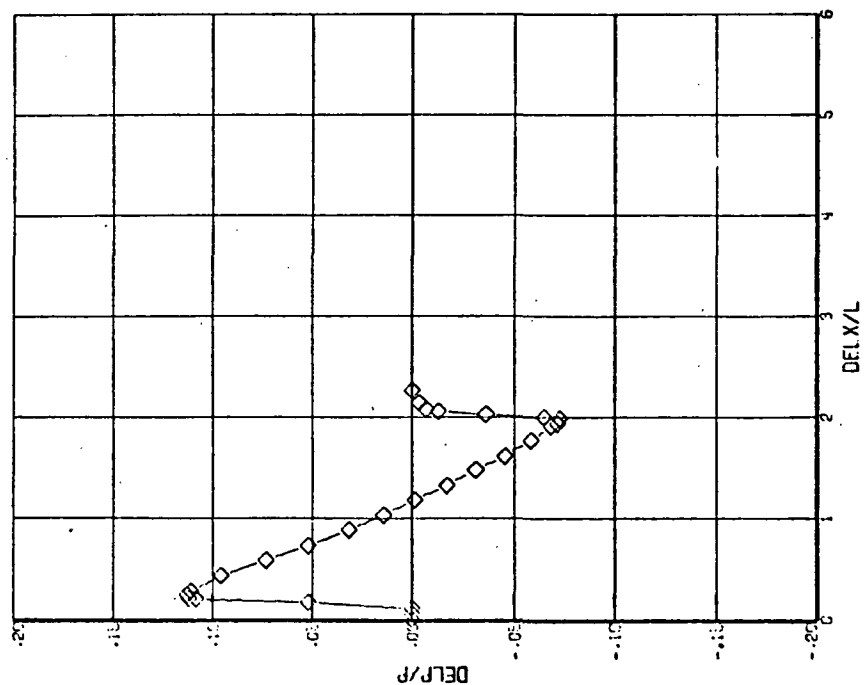
MECH = 1.990 ALPHA = 60.000 PHI = 0.000 W/L = 4.5600

PLOT 22



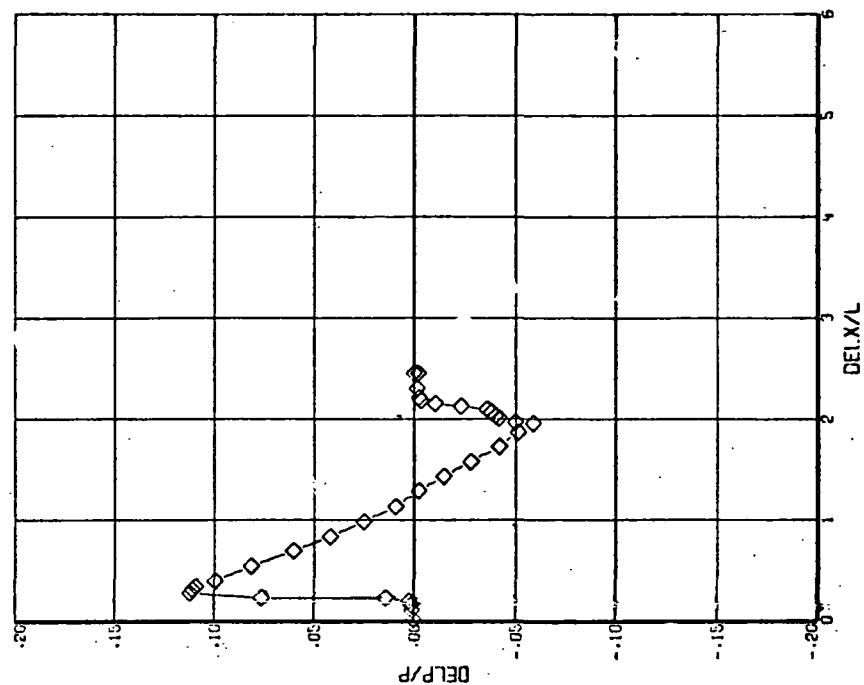
WCH = 2.170 ALPHA = 10.000 PHI = 0.000 H/L = 2.9670

PLOT 23



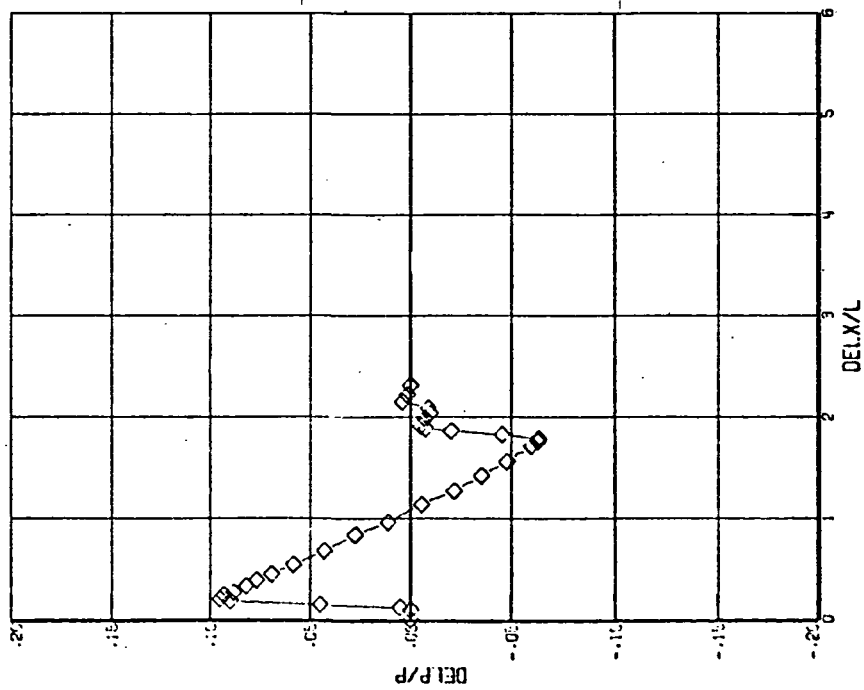
WCH = 2.170 ALPHA = 10.000 PHI = 30.000 H/L = 2.9670

PLOT 24



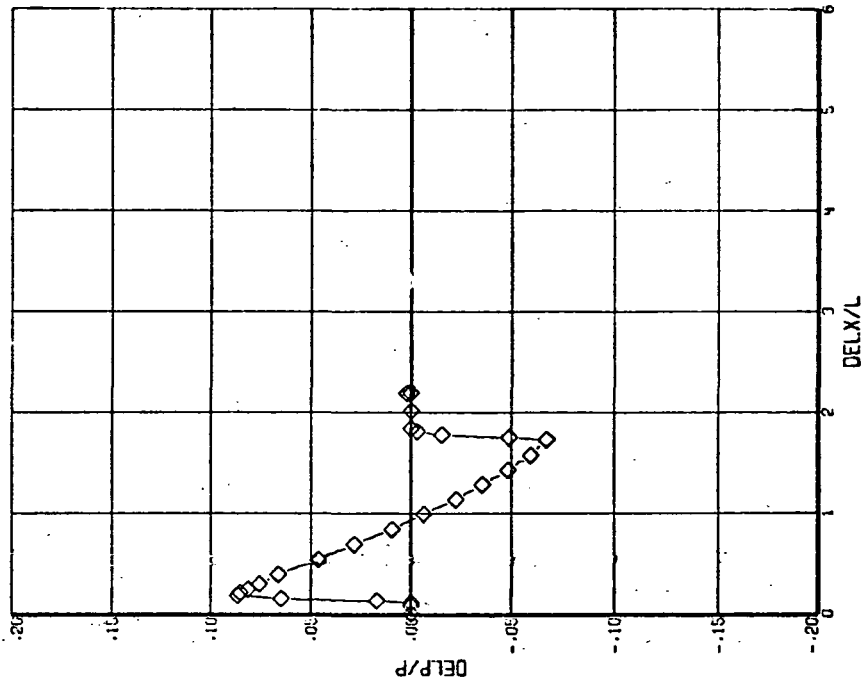
$\rho_{\text{CH}} = 2.170$ $\text{ALPHA} = 10.000$ $\text{PHI} = 60.000$ $\text{M/L} = 2.9670$

PLOT 25



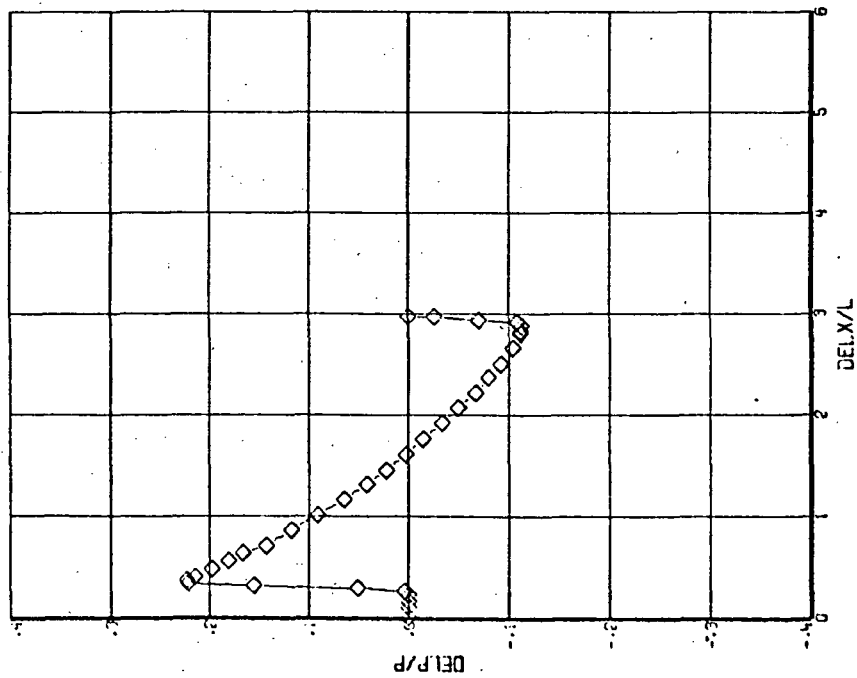
$\rho_{\text{CH}} = 2.170$ $\text{ALPHA} = 10.000$ $\text{PHI} = 90.000$ $\text{M/L} = 2.9670$

PLOT 26



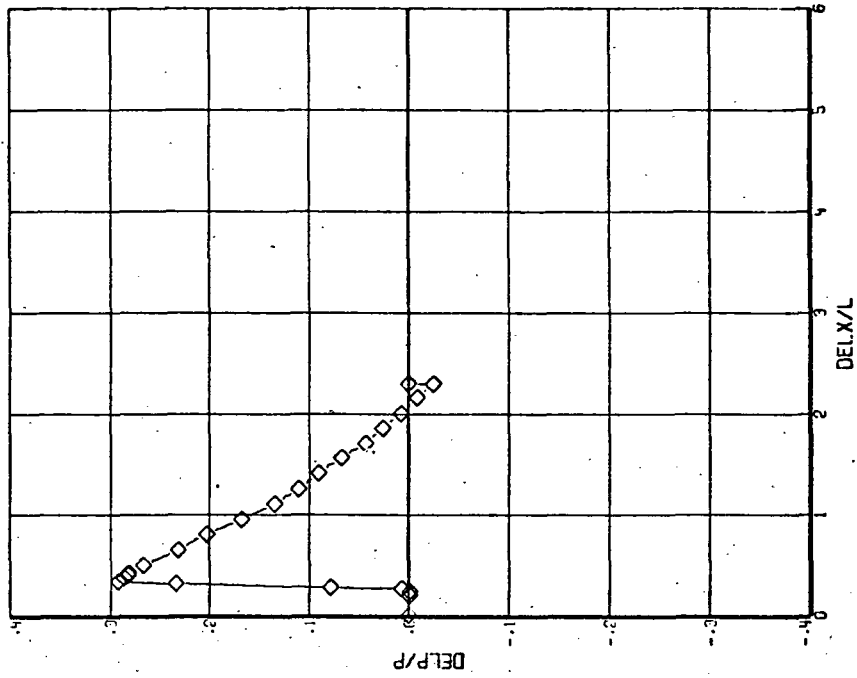
MOCH = 2.170 ALPHA = 25.000 PHI = 0.000 W/L = 2.8930

PLOT 27



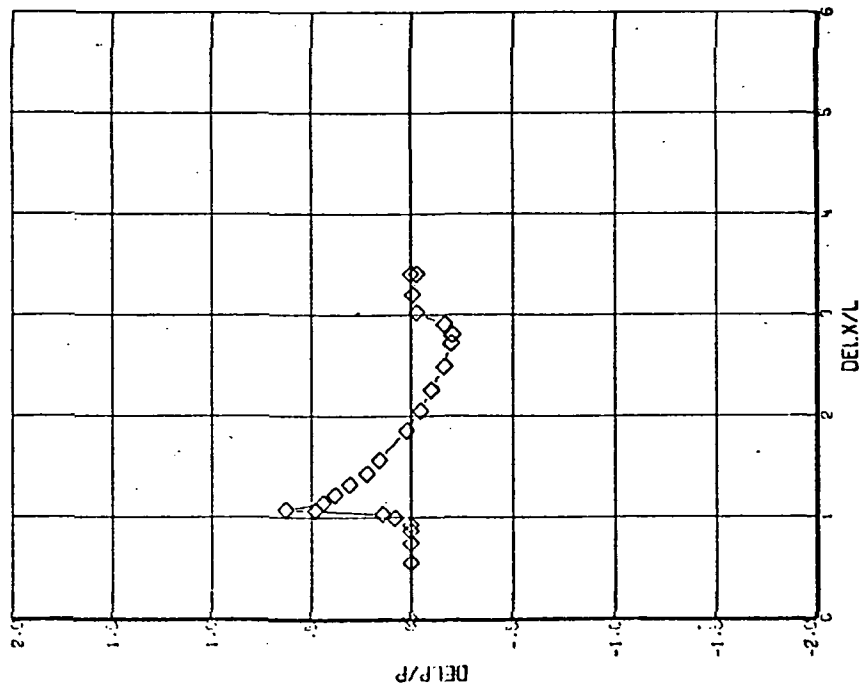
MOCH = 2.170 ALPHA = 50.000 PHI = 0.000 W/L = 3.4000

PLOT 28



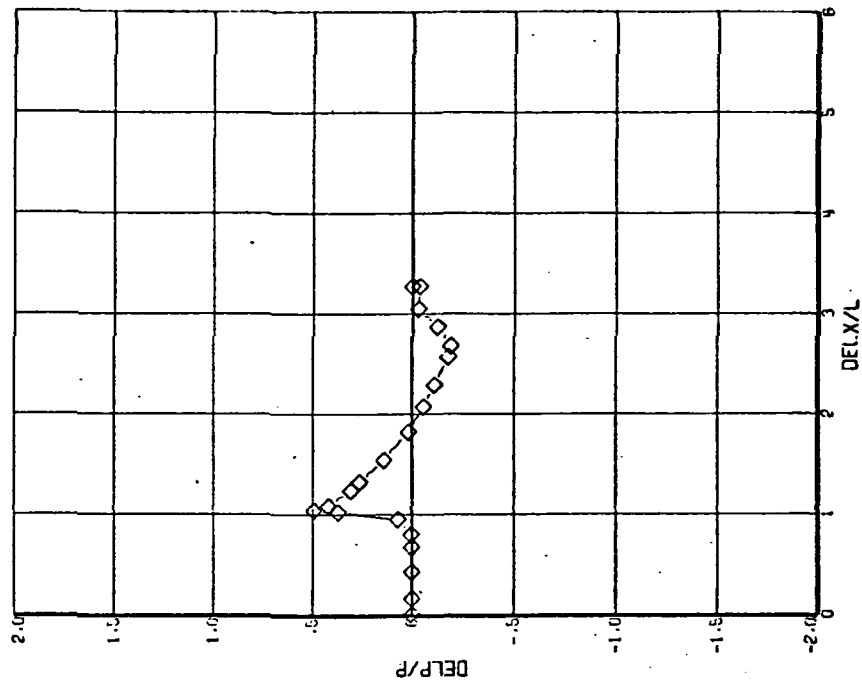
$\text{MACH} = 2.200$ $\text{ALPHA} = 25.000$ $\text{PHI} = 0.000$ $\text{W/L} = 1.4800$

PLOT 29



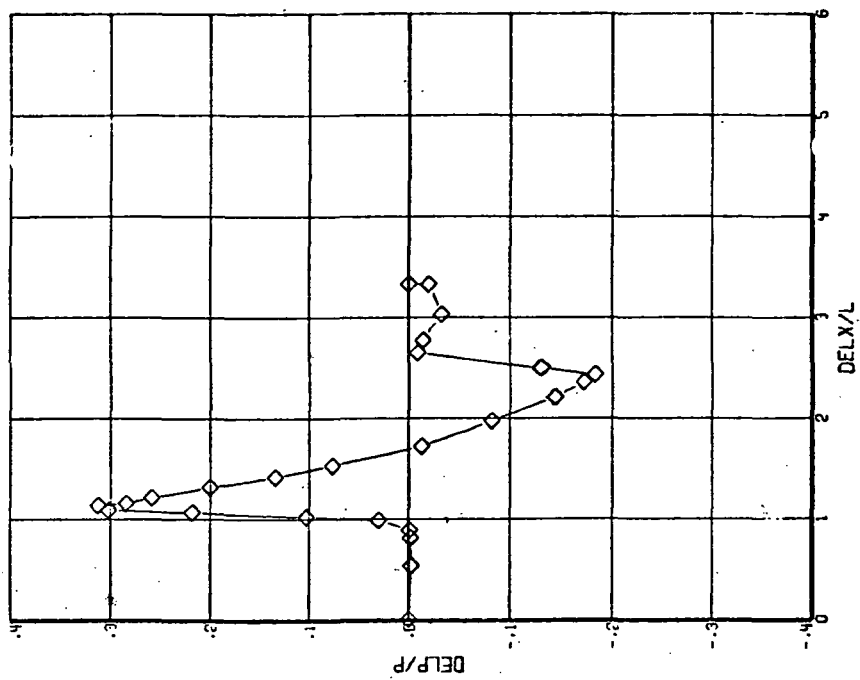
$\text{MACH} = 2.200$ $\text{ALPHA} = 25.000$ $\text{PHI} = 25.800$ $\text{W/L} = 1.4300$

PLOT 30



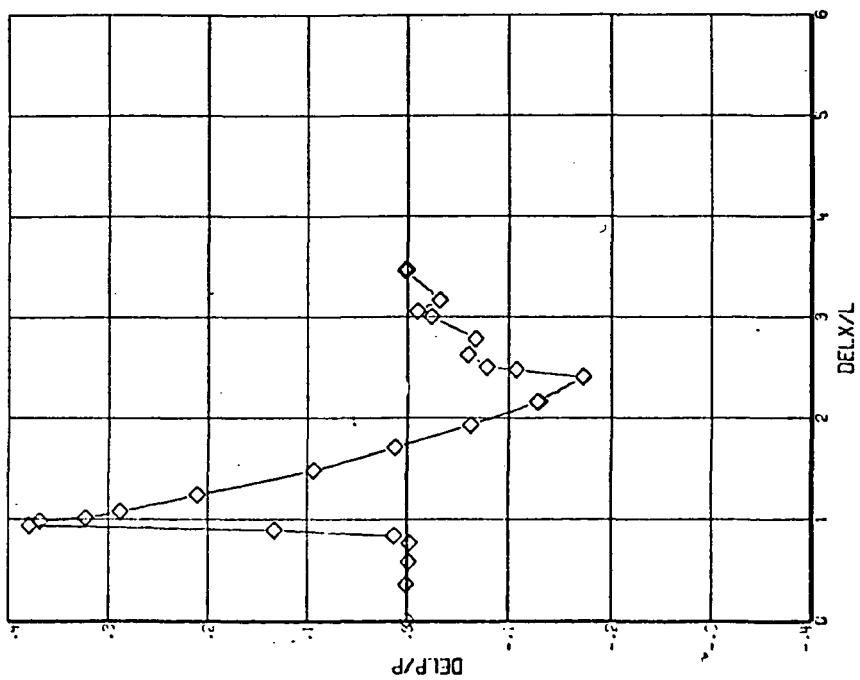
MACH = 2.200 ALPHA = 26.000 PHI = 80.700 M/L = 1.3100

PLOT 32



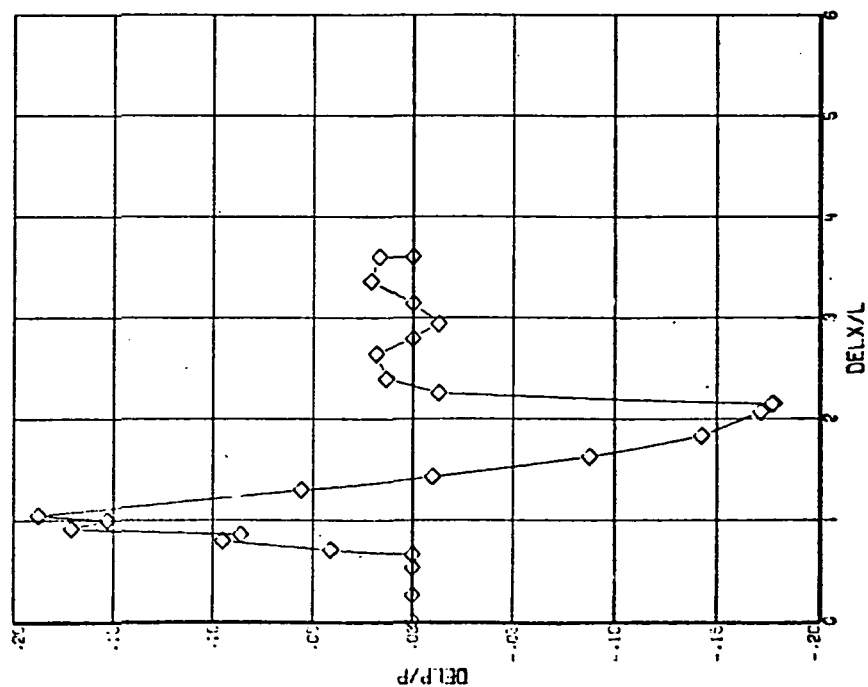
MACH = 2.200 ALPHA = 26.000 PHI = 82.300 M/L = 1.3600

PLOT 31



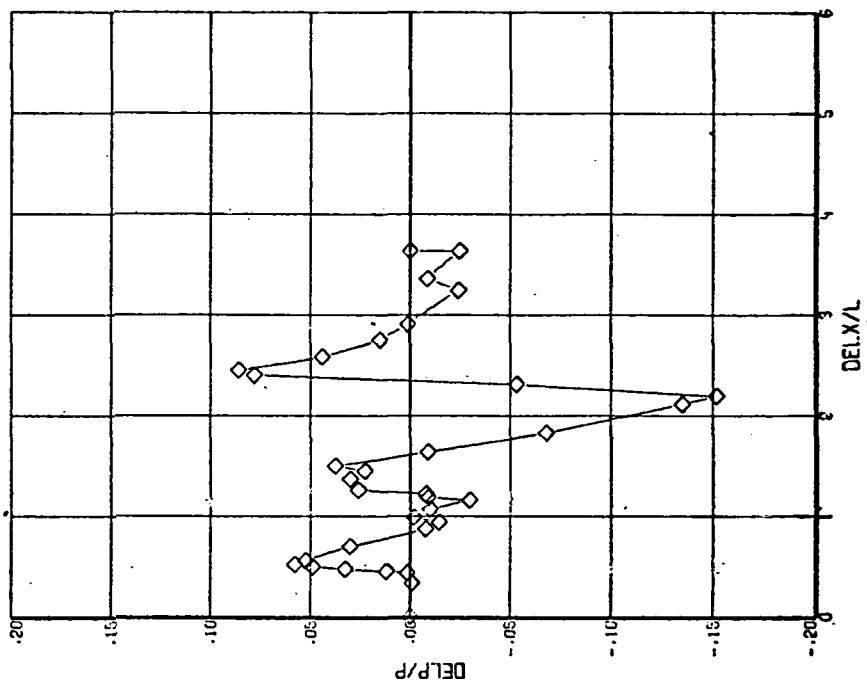
NRCH = 2.200 ALPHR = 25.000 PHI = 111.200 H/L = 1.2000

PLOT 33



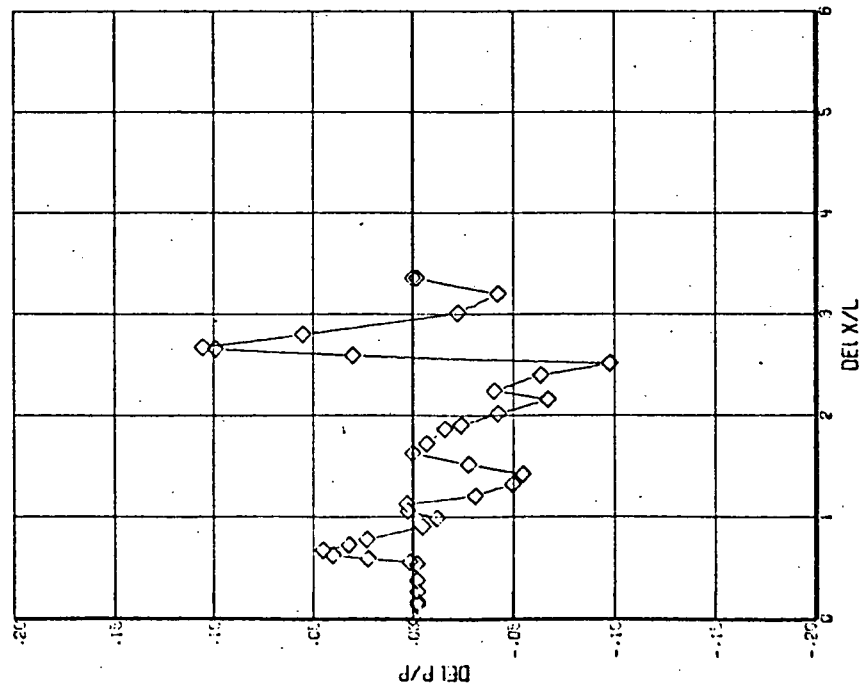
NRCH = 2.200 ALPHR = 25.000 PHI = 144.600 H/L = 1.1300

PLOT 34



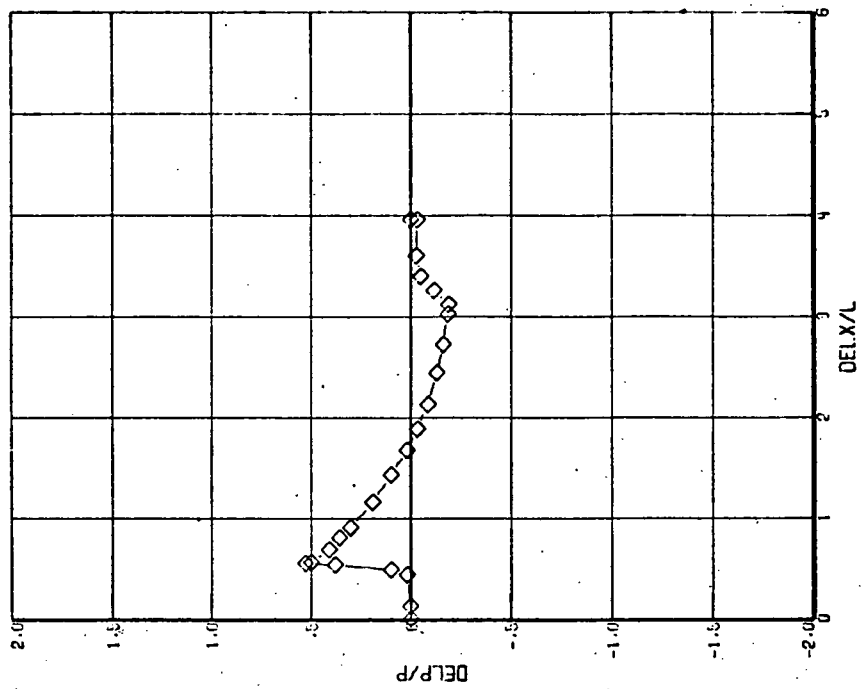
MACH = 2.200 ALPHA = .25.000 PHI = 180.000 H/L = 1.1000

PLOT 35



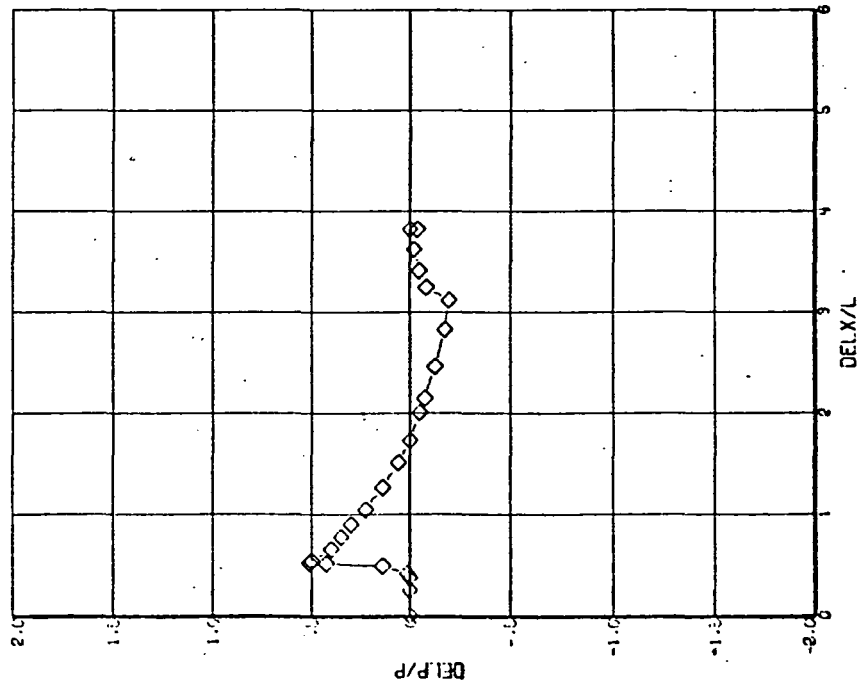
MACH = 2.200 ALPHA = 45.000 PHI = 0.000 H/L = 2.1000

PLOT 36



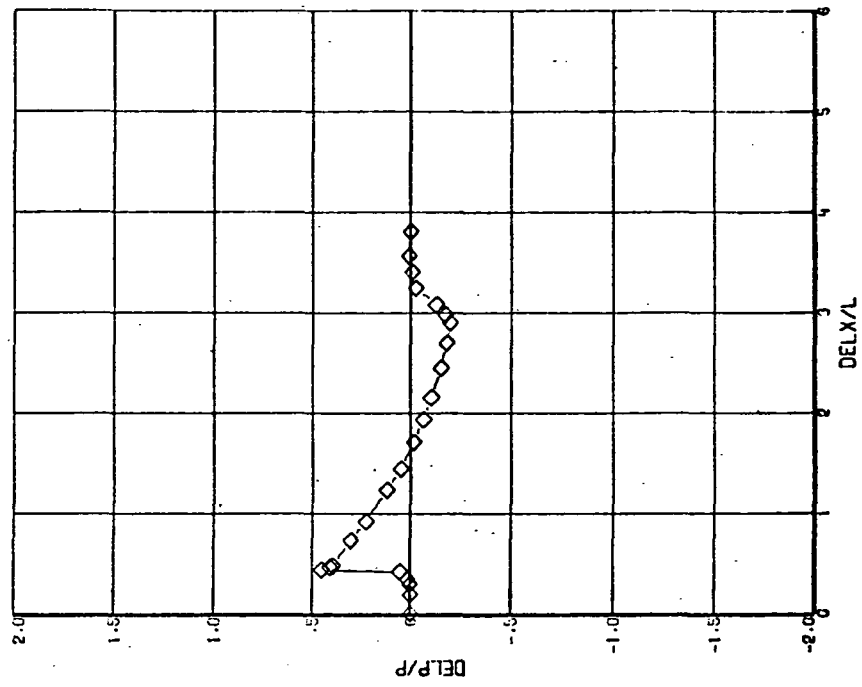
MACH = 2.200 ALPHA = 45.000 PHI = 25.100 N/L = 2.0900

PLOT 37



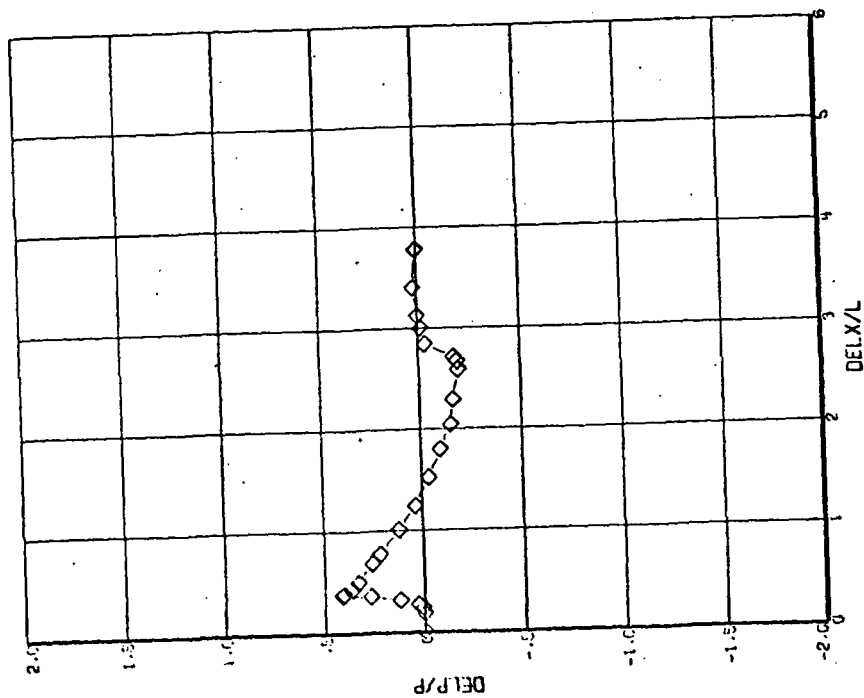
MACH = 2.200 ALPHA = 45.000 PHI = 51.000 N/L = 1.3700

PLOT 38



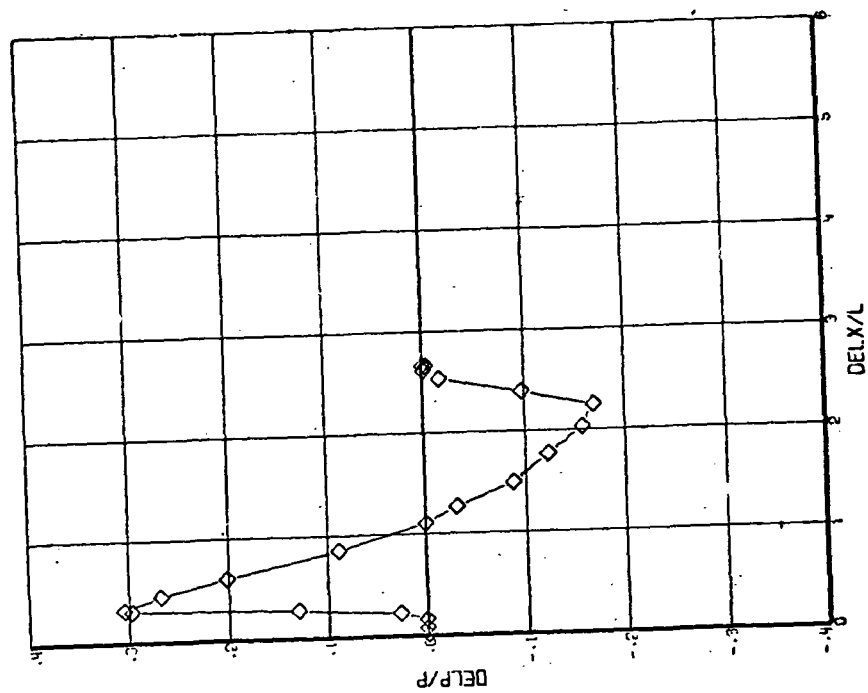
MECH = 2.200 μ ALPHA = 45.000 PHI = 79.900 W/L = 1.8300

PLOT 39



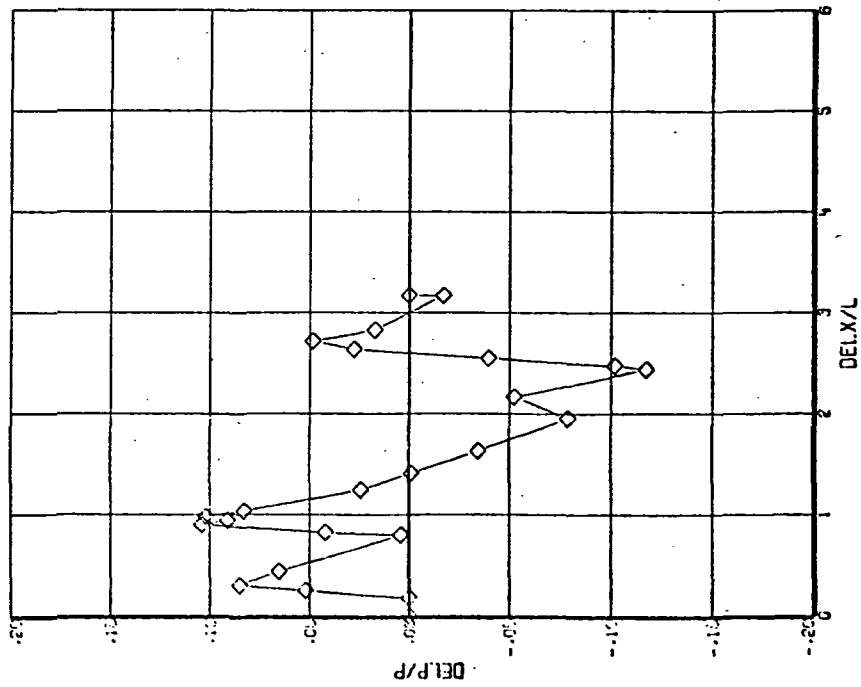
MECH = 2.200 μ ALPHA = 45.000 PHI = 109.300 W/L = 1.6400

PLOT 40



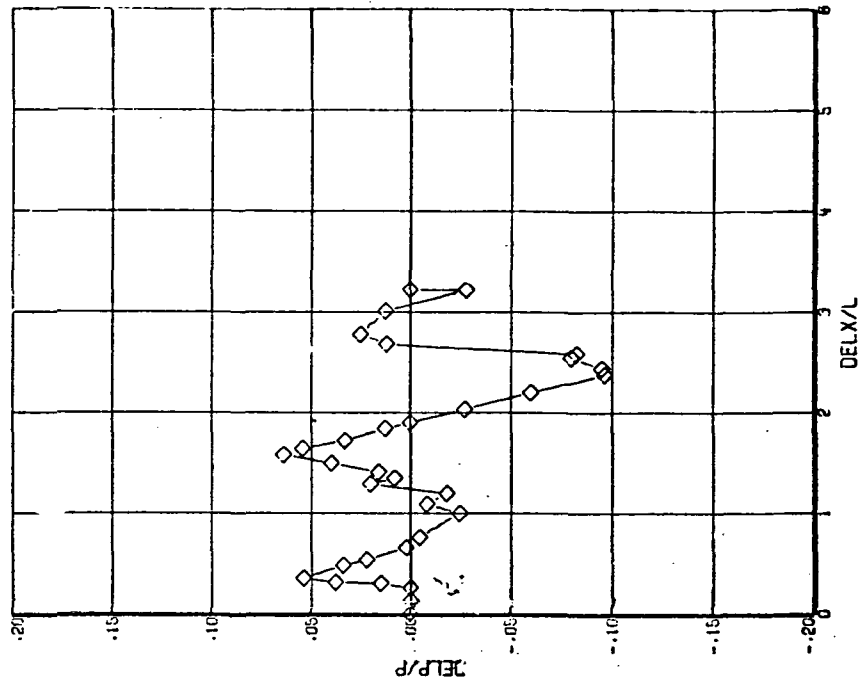
MRCH = 2.200 ALPHA = 45.000 PHI = 193.200 H/L = 1.0000

PLOT 41



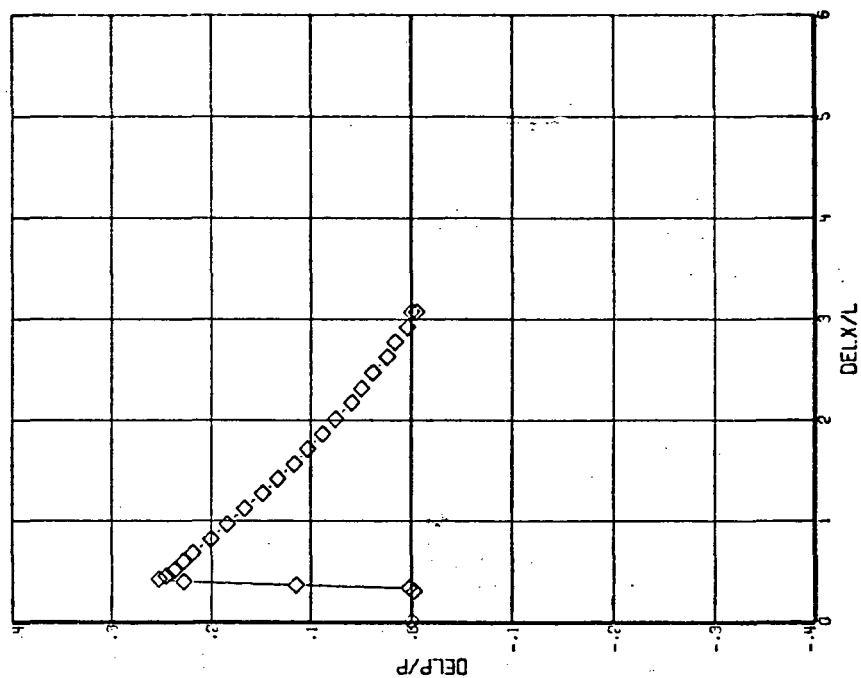
MRCH = 2.200 ALPHA = 45.000 PHI = 180.000 H/L = 1.4500

PLOT 42



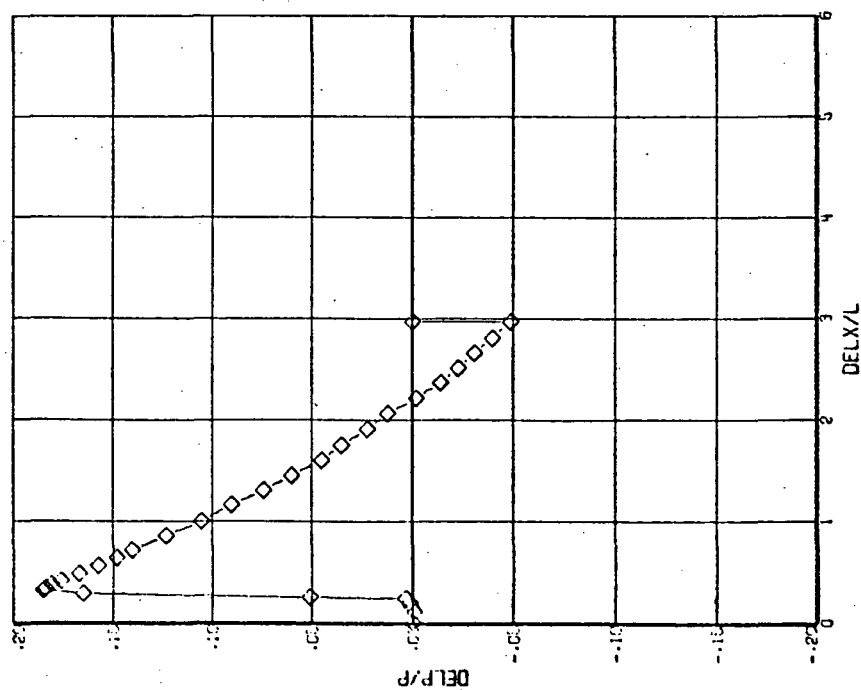
MECH = 2.700 ALPHA = 60.000 PHI = 0.000 H/L = 4.7870

PLOT 44



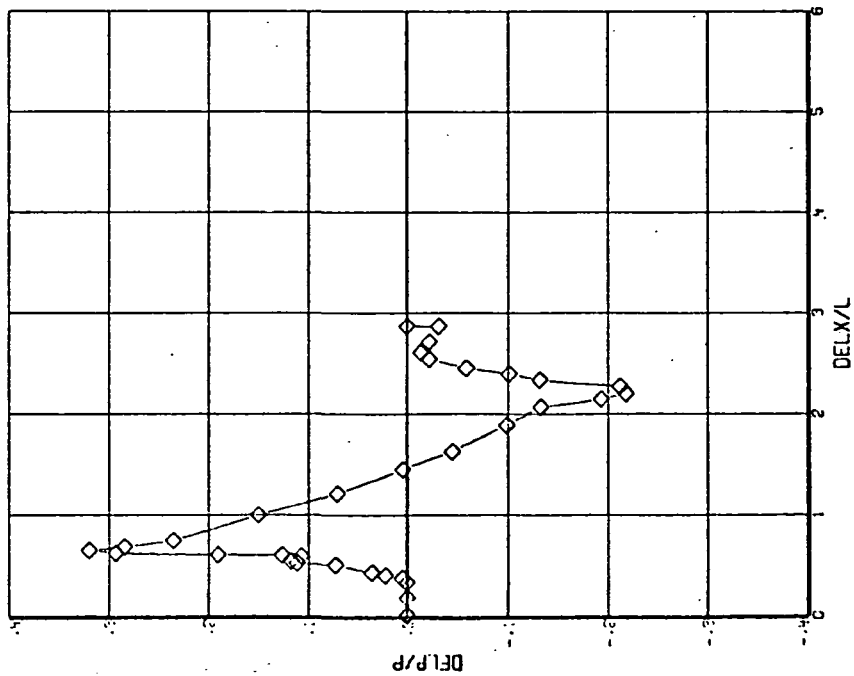
MECH = 2.700 ALPHA = 25.000 PHI = 0.000 H/L = 4.1350

PLOT 43



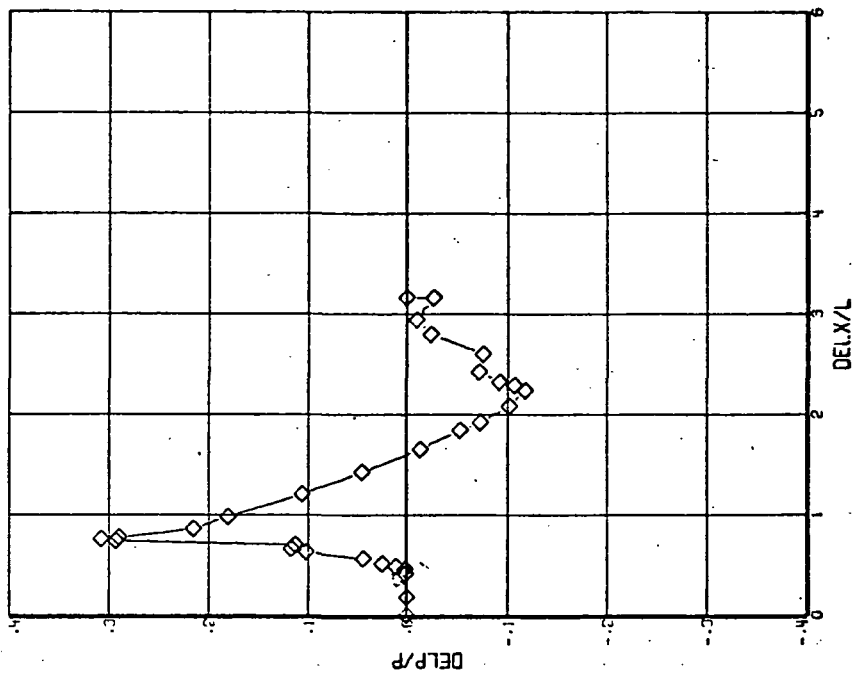
$\mu_{SCH} = 3.000$ $\alpha_{PWR} = 10.000$ $\phi_{HI} = 0.000$ $N/L = 1.3000$

PLOT 45



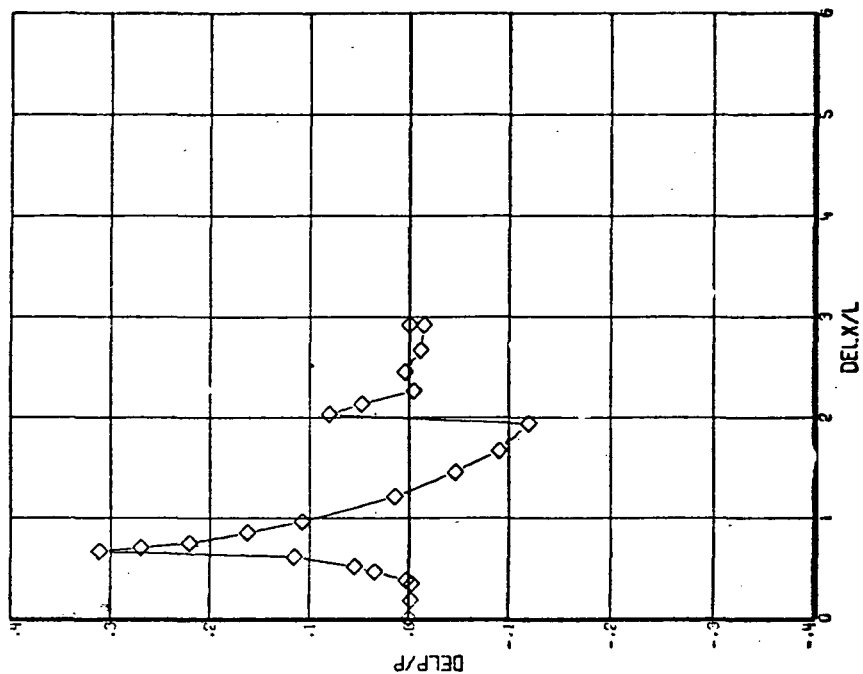
$\mu_{SCH} = 3.000$ $\alpha_{PWR} = 10.000$ $\phi_{HI} = 29.100$ $N/L = 1.3000$

PLOT 46



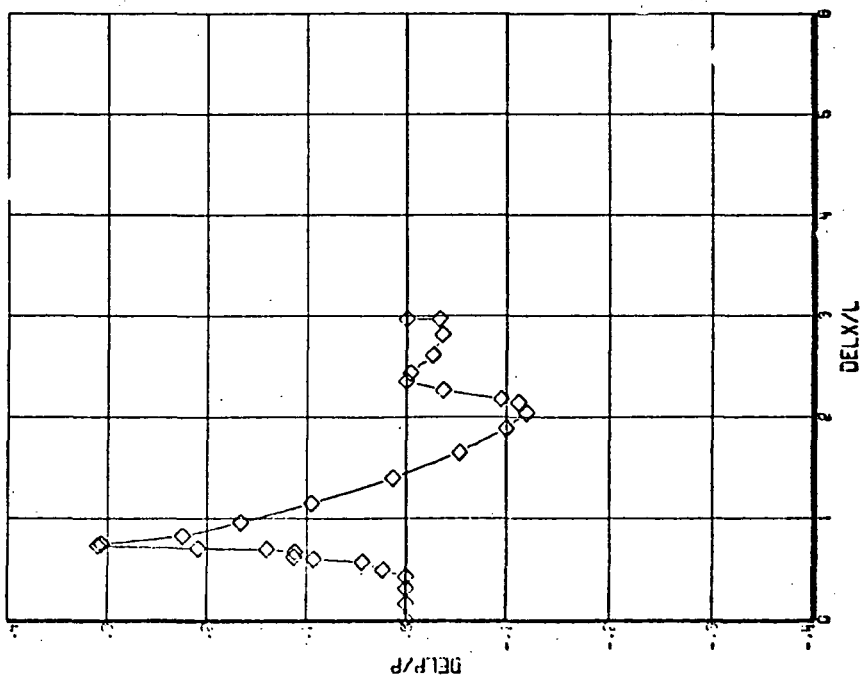
$\mu_{CH} = 3.000$ $\mu_{PH} = 10.000$ $\mu_{L} = 96.100$ $N/L = 1.2800$

PLOT 48



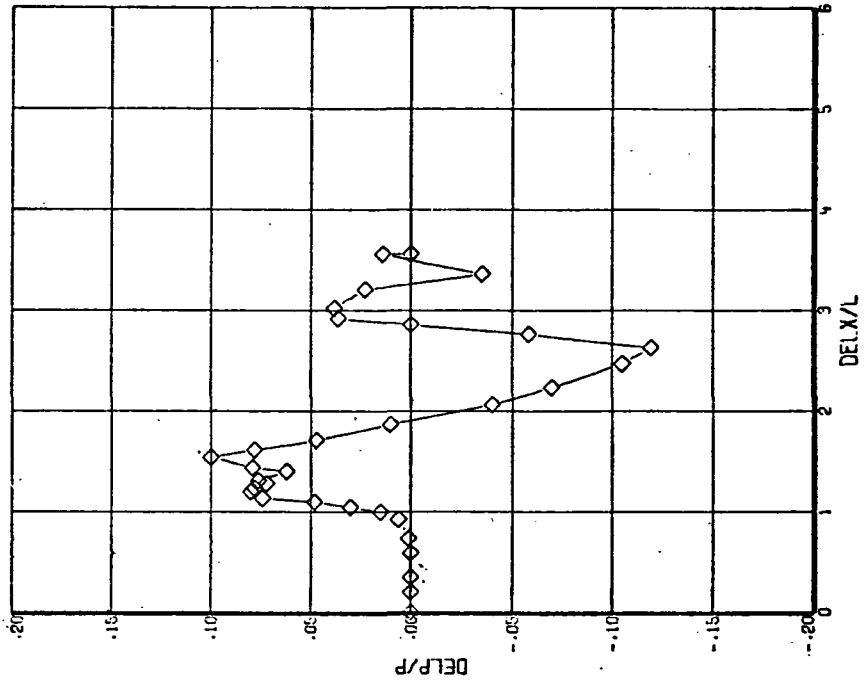
$\mu_{CH} = 3.000$ $\mu_{PH} = 10.000$ $\mu_{L} = 56.700$ $N/L = 1.3100$

PLOT 47



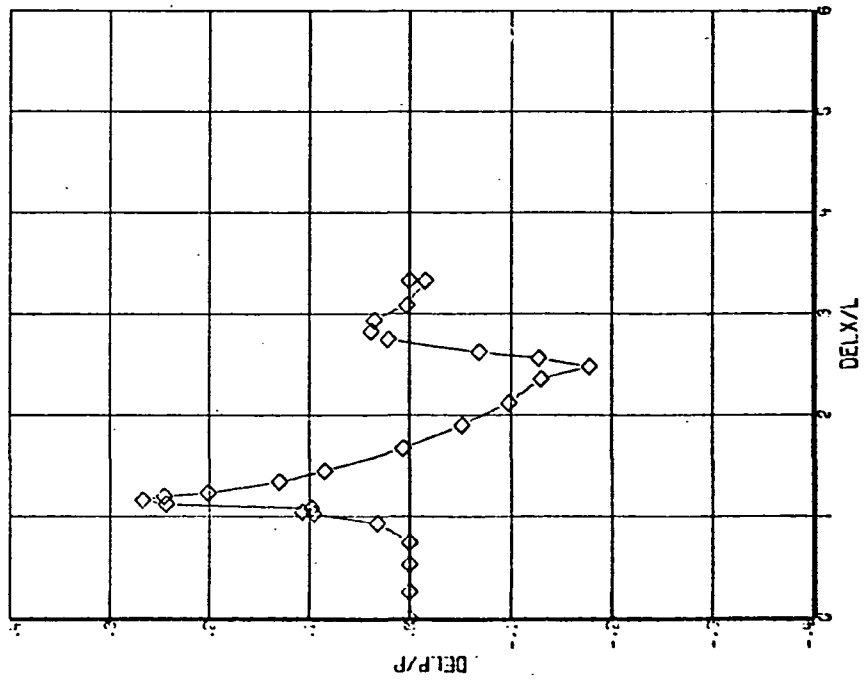
MECH = 3.000 ALPHA = 10.000 PHI = 149.000 W/L = 1.2300

PLOT 50



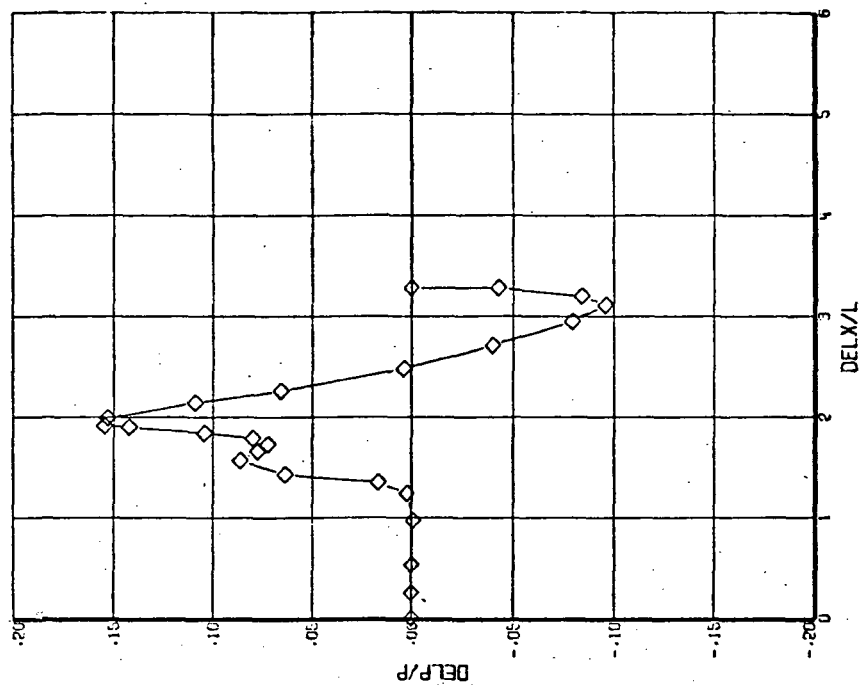
MECH = 3.000 ALPHA = 10.000 PHI = 116.700 W/L = 1.2400

PLOT 49



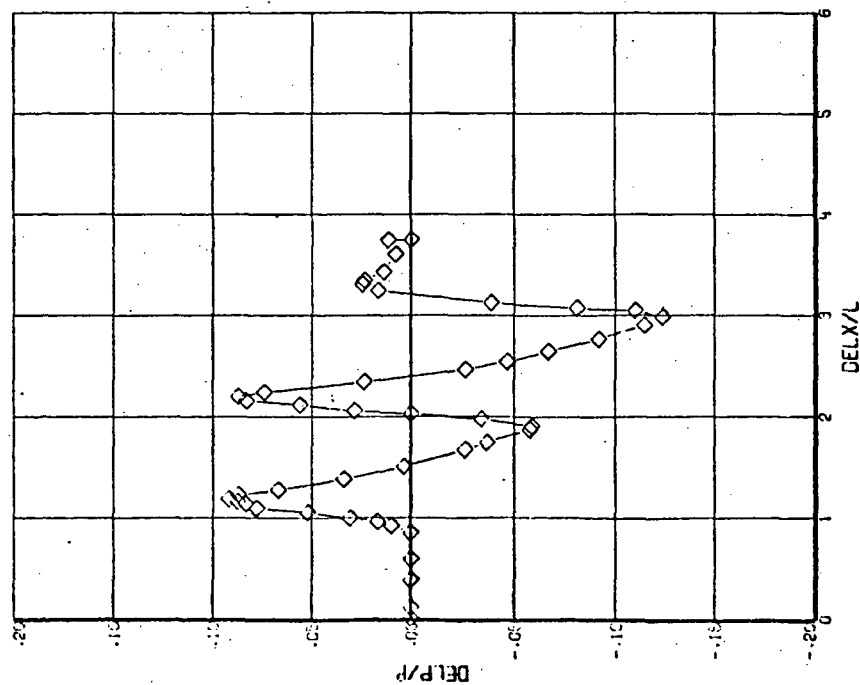
MECH = 3.900 ALPHA = 0.000 PHI = 0.000 W/L = 1.2800

PLOT 52



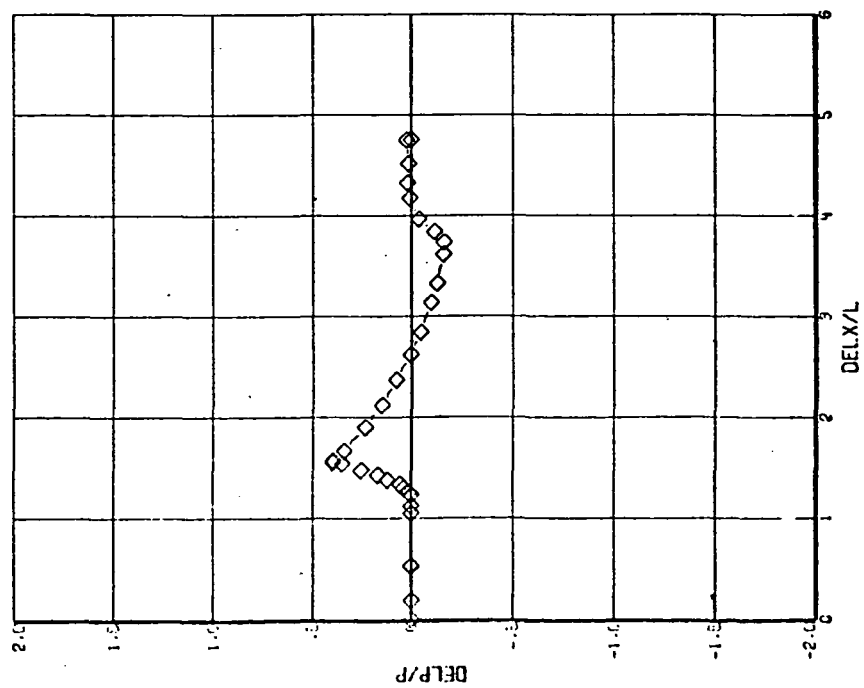
MECH = 3.000 ALPHA = 10.000 PHI = 180.000 W/L = 1.2200

PLOT 51



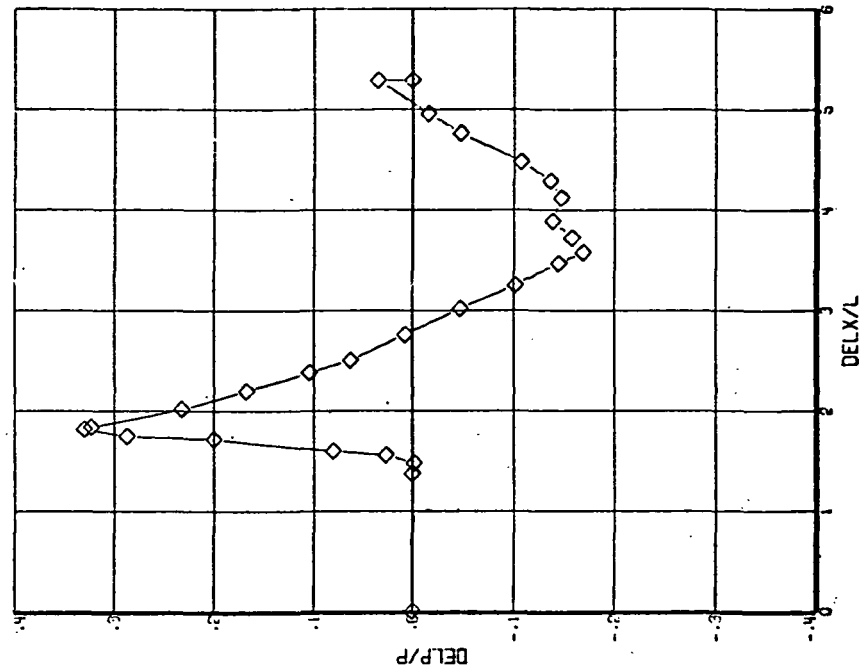
MACH = 3.380 ALPHA = 10.000 PHI = 0.000 H/L = 1.3300

PLOT 53



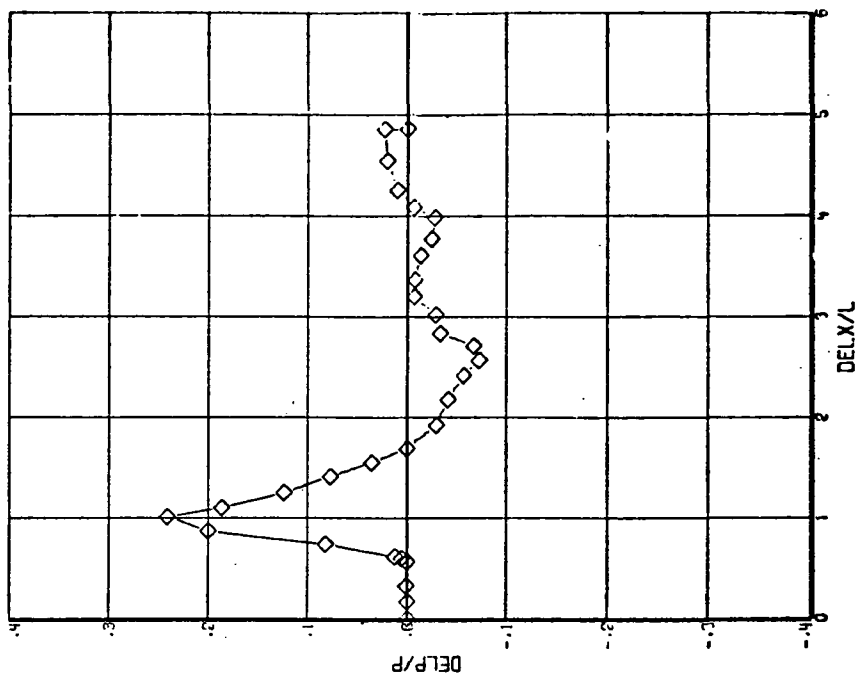
MACH = 3.380 ALPHA = 10.000 PHI = 28.100 H/L = 1.3300

PLOT 54



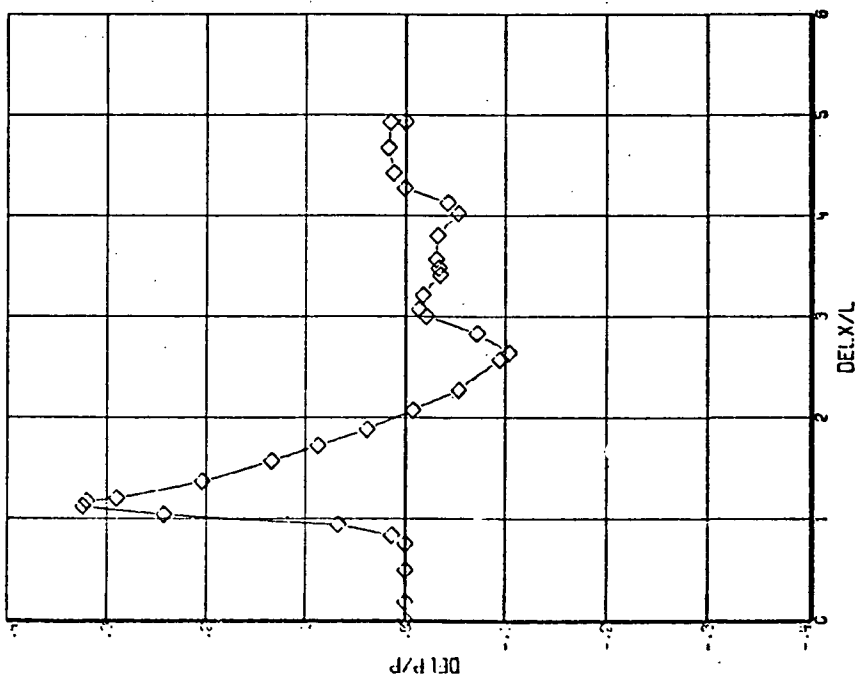
$\mu_{CH} = 3.980$ $\alpha_{PMA} = 10.000$ $\phi_{H} = 86.100$ $M/L = 1.2800$

PLOT 56



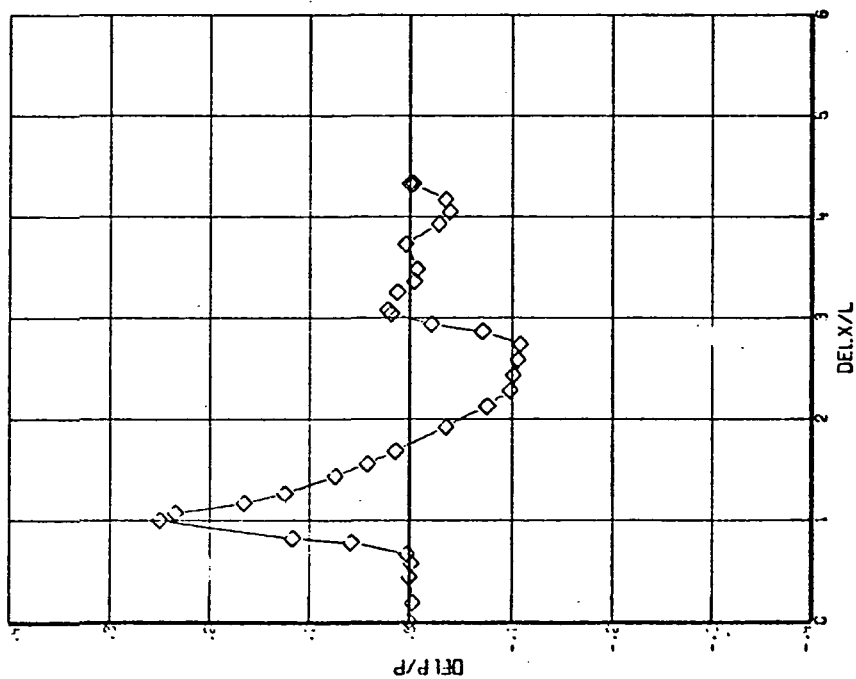
$\mu_{CH} = 3.980$ $\alpha_{PMA} = 10.000$ $\phi_{H} = 56.700$ $M/L = 1.3000$

PLOT 55



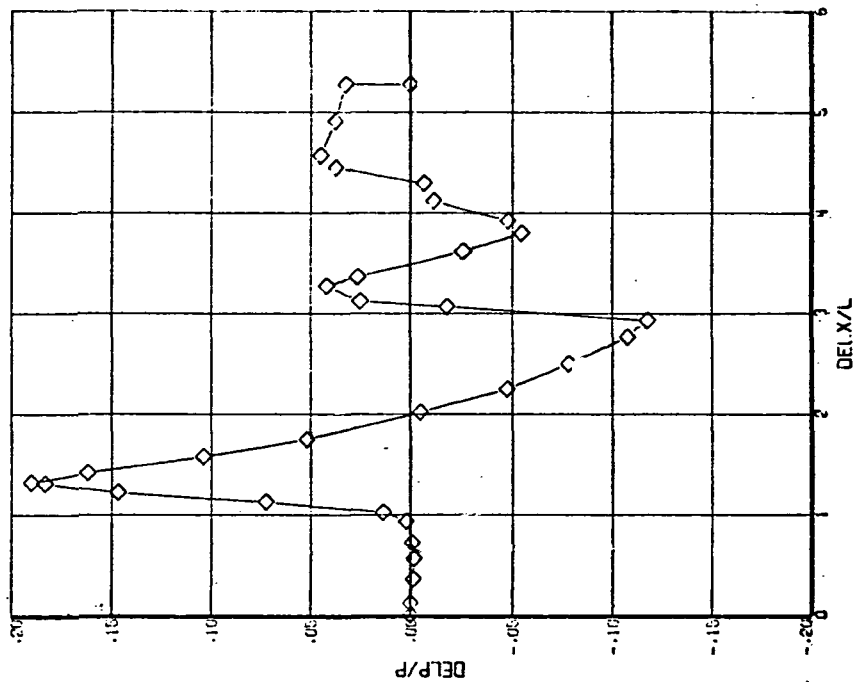
WCH = 3.990 RPH = 10.000 PHI = 116.500 W/L = 1.2000

PLOT 57



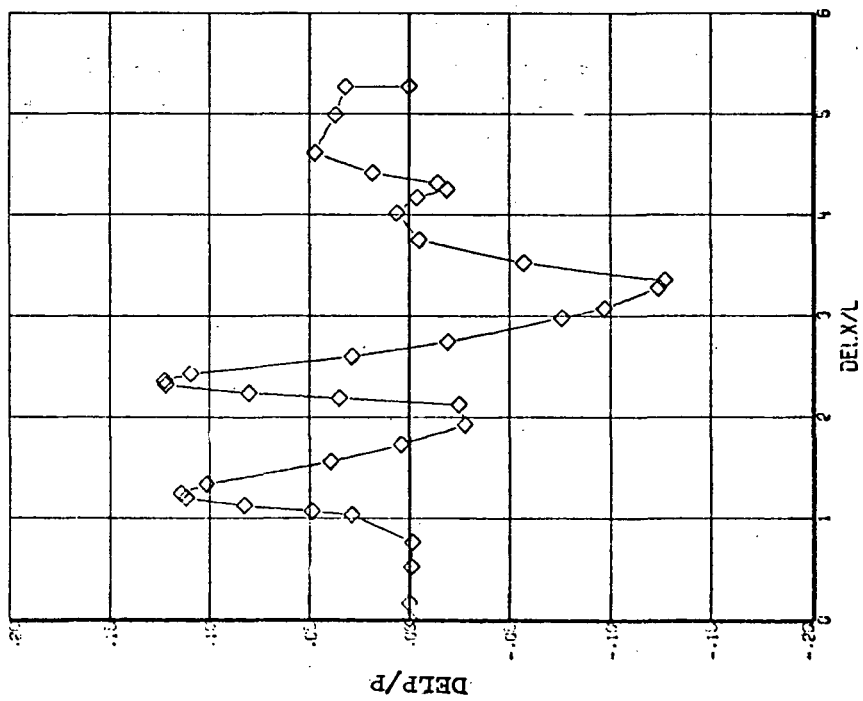
WCH = 3.990 RPH = 10.000 PHI = 149.000 W/L = 1.2000

PLOT 58



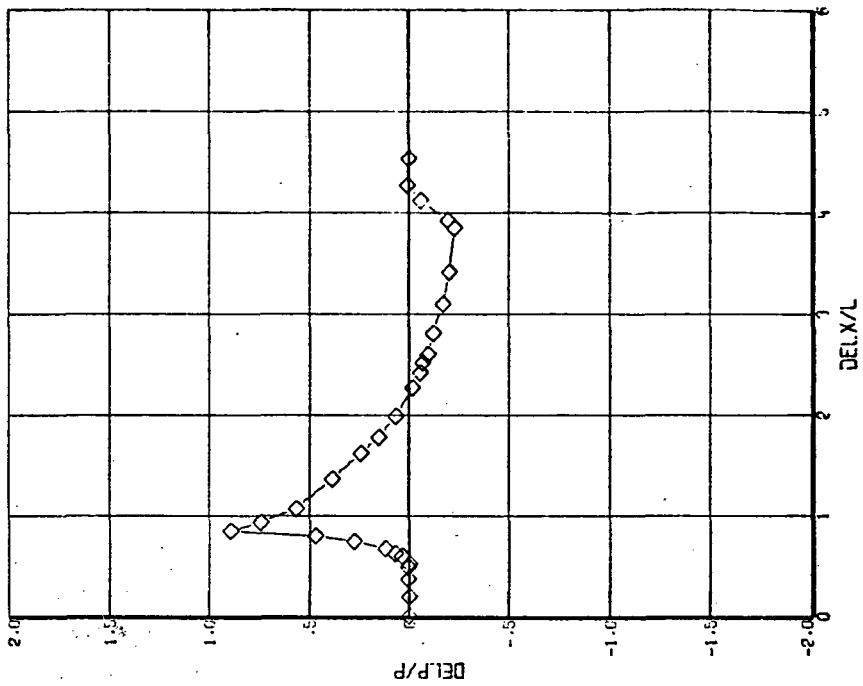
WCH = 3.390 ALPHA = 10.000 PHI = 100.000 W/L = 1.2100

PLOT 59



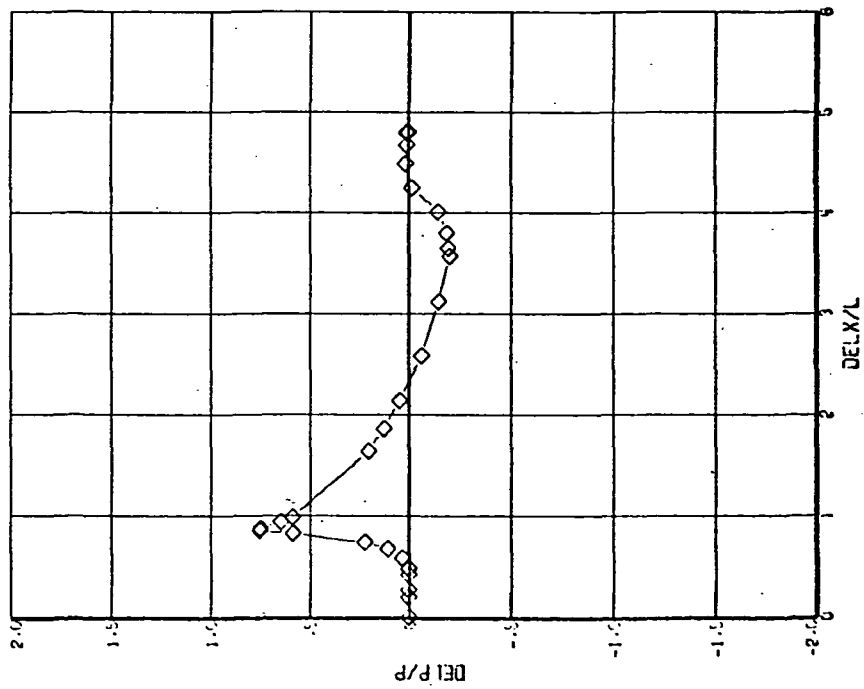
WCH = 3.380 ALPHA = 25.000 PHI = 0.000 W/L = 1.4600

PLOT 60



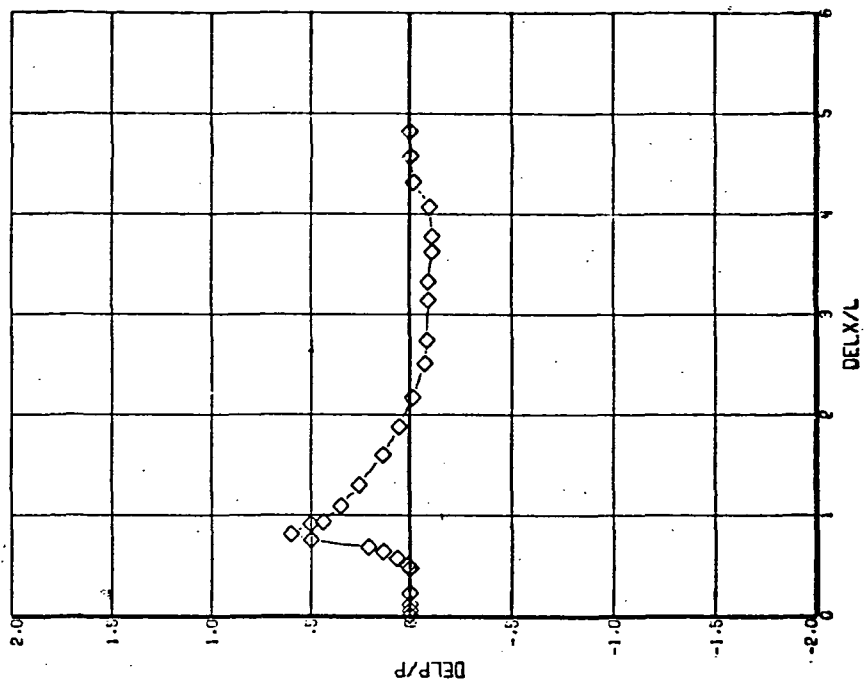
$\mu_{CH} = 3.990$ $\alpha_{PHA} = 25.000$ $\phi_{HI} = 25.800$ $\mu/L = 1.4300$

PLOT 61



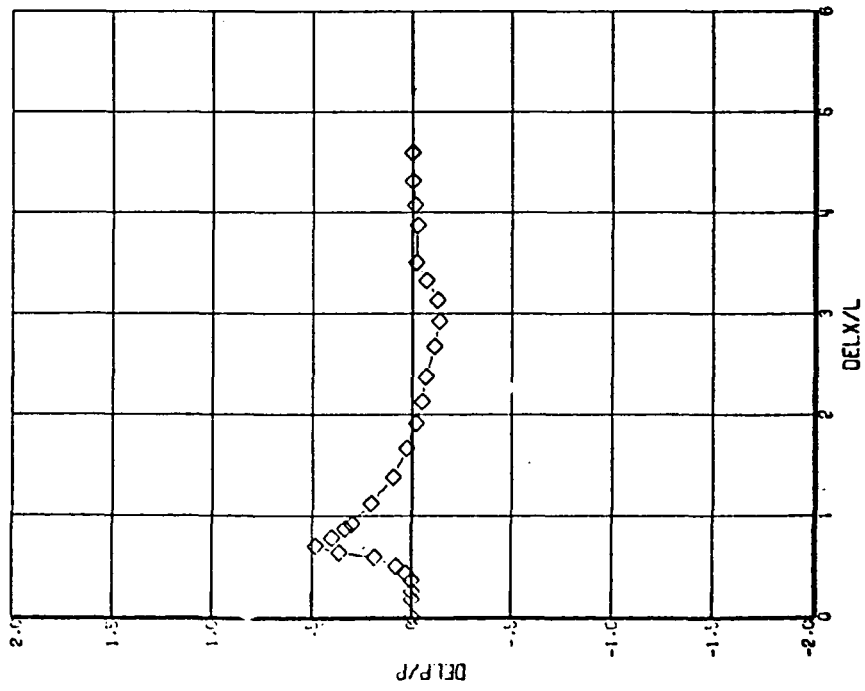
$\mu_{CH} = 3.980$ $\alpha_{PHA} = 25.000$ $\phi_{HI} = 52.300$ $\mu/L = 1.3700$

PLOT 62



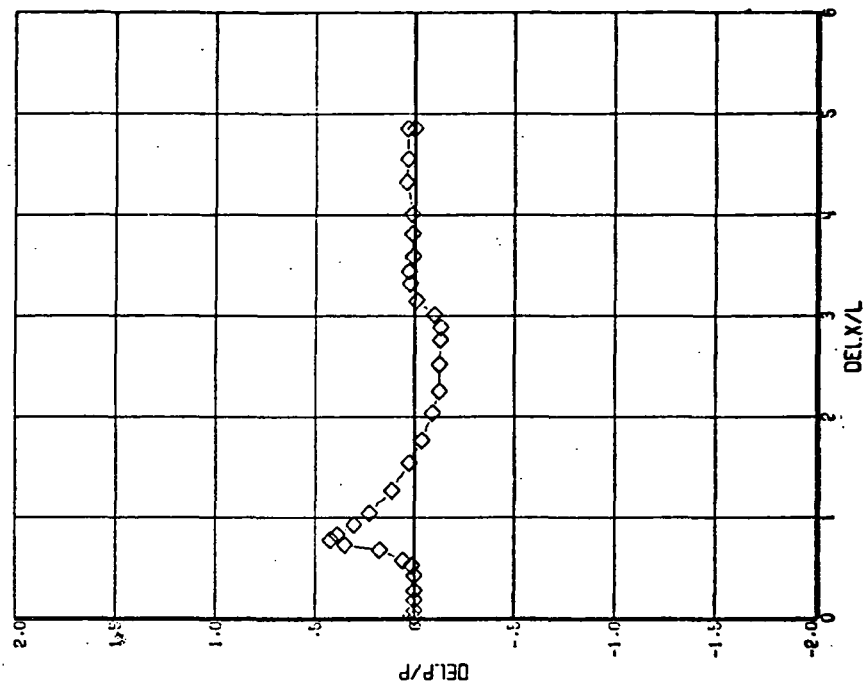
WICH = 3.990 ALPHA = 25.000 PHI = 80.500 H/L = 1.3000

PLOT 63



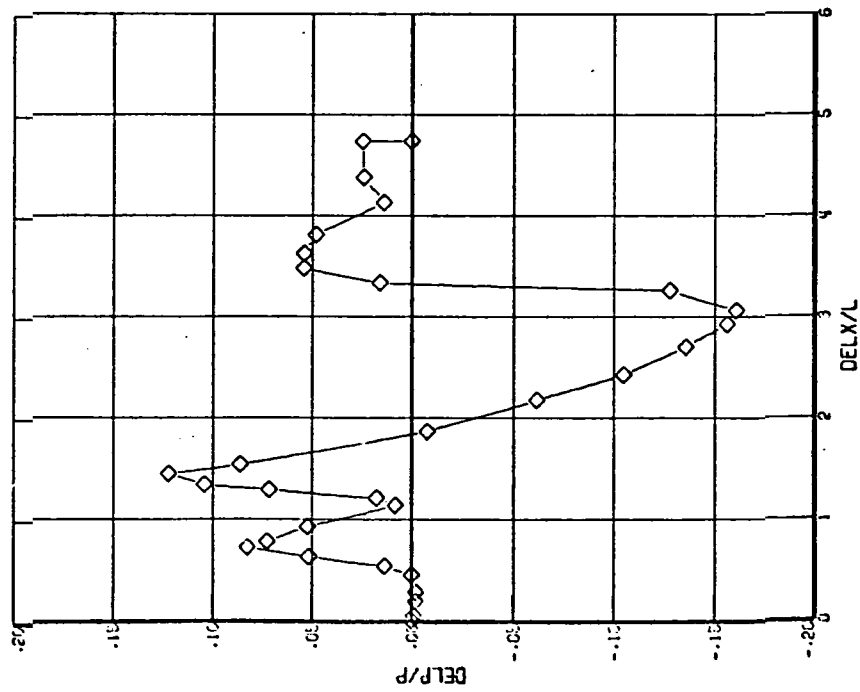
WICH = 3.990 ALPHA = 25.000 PHI = 111.100 H/L = 1.1800

PLOT 64



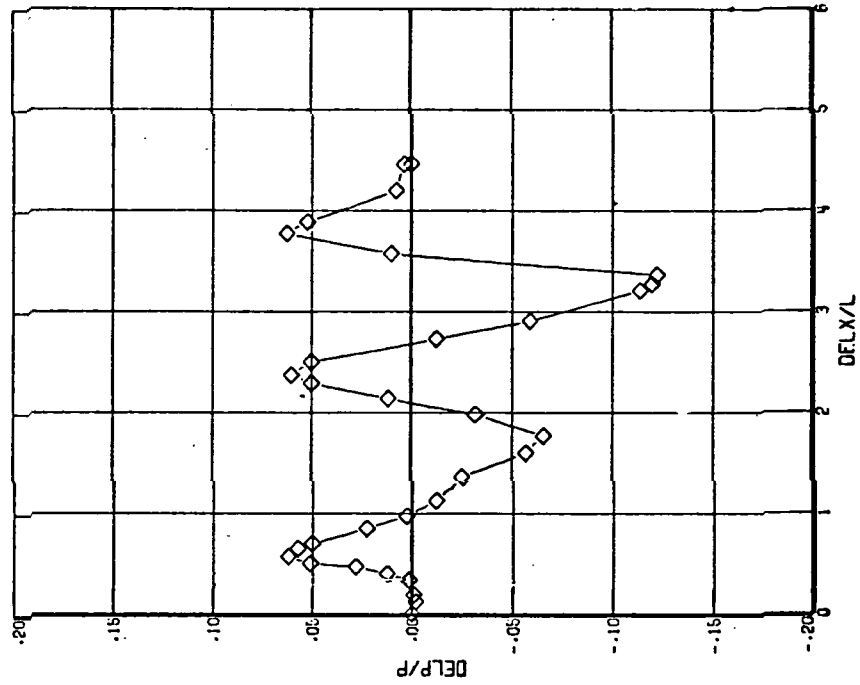
WCH = 3.980 ALPHA = 26.000 PHI = 144.600 W/L = 1.1100

PLOT 65



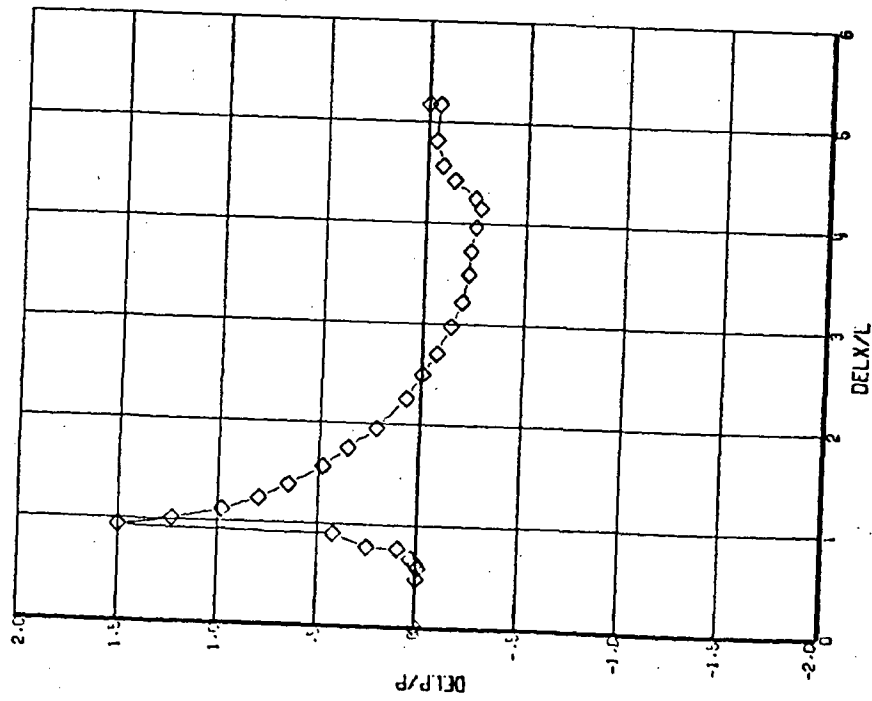
WCH = 3.980 ALPHA = 26.000 PHI = 180.000 W/L = 1.0500

PLOT 66



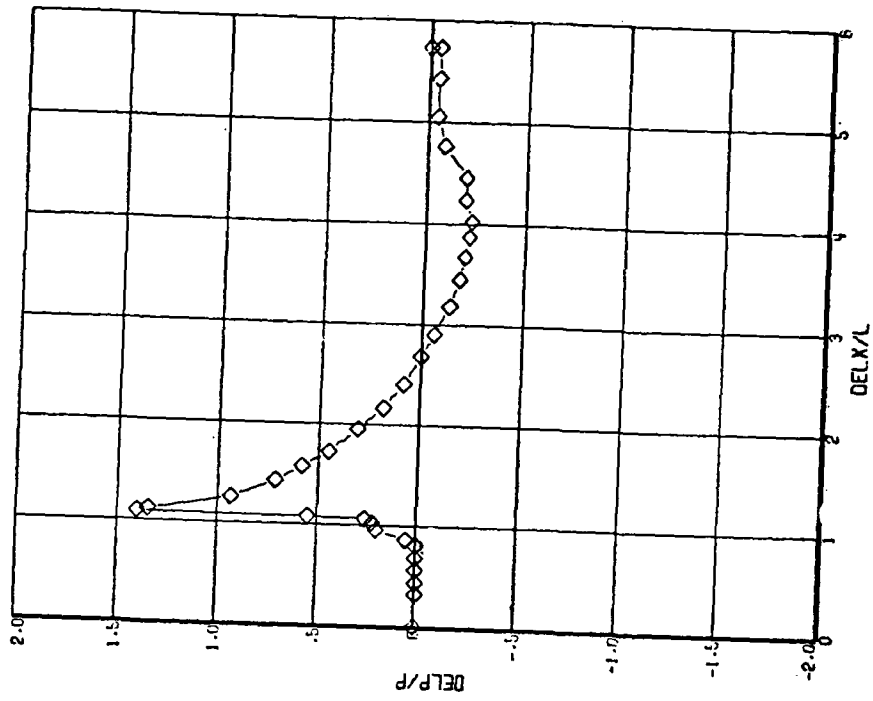
$\mu_{CH} = 3.990$ $\alpha_{PHR} = 45.000$ $\phi_{HI} = 0.000$ $\lambda = 1.6100$

PLOT 67



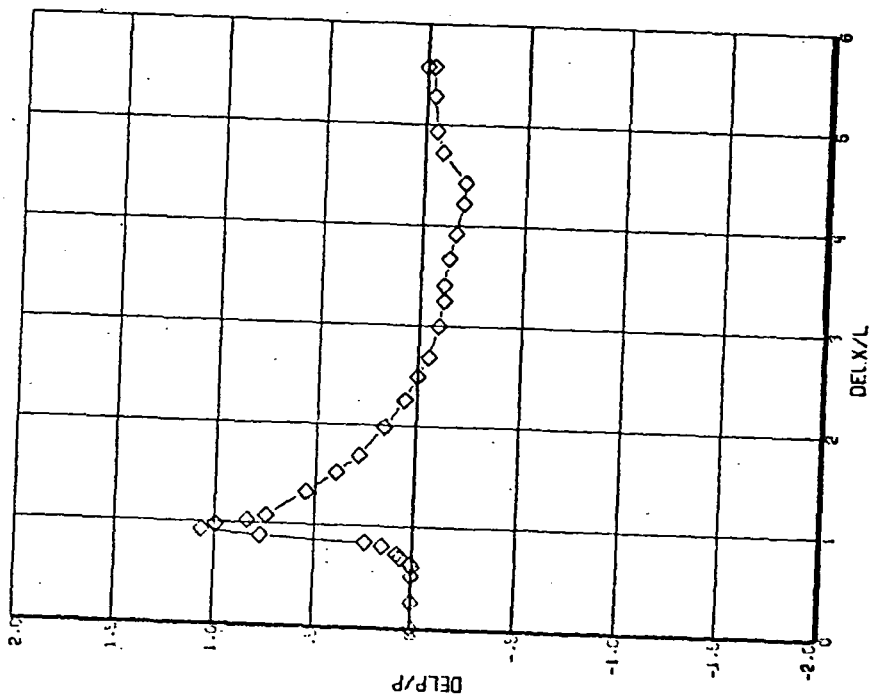
$\mu_{CH} = 3.990$ $\alpha_{PHR} = 45.000$ $\phi_{HI} = 23.500$ $\lambda = 1.5700$

PLOT 68



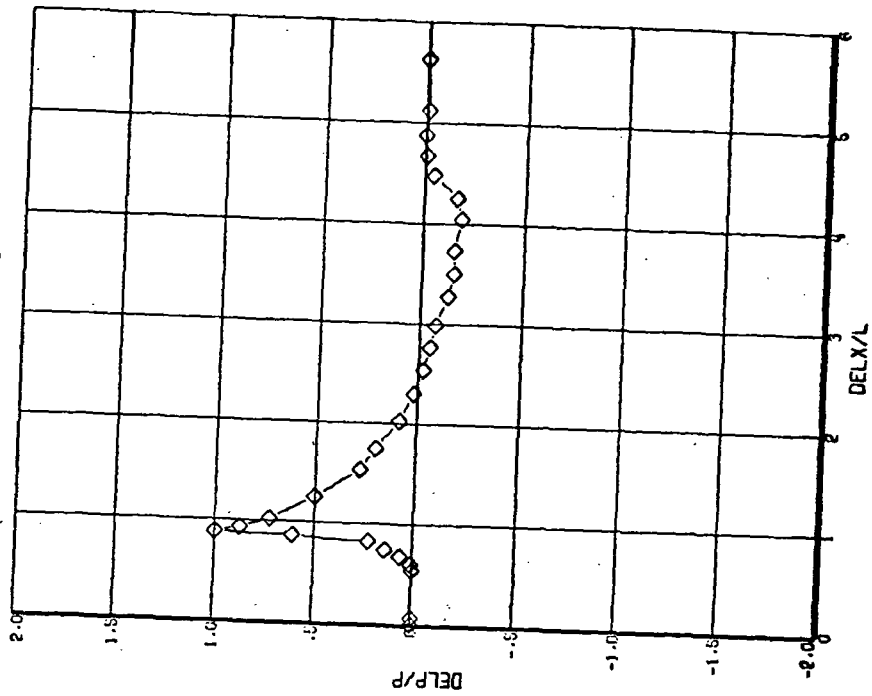
MACH = 3.390 ALPHA = 45.000 PHI = 47.500 W/L = 1.4600

PLOT 69



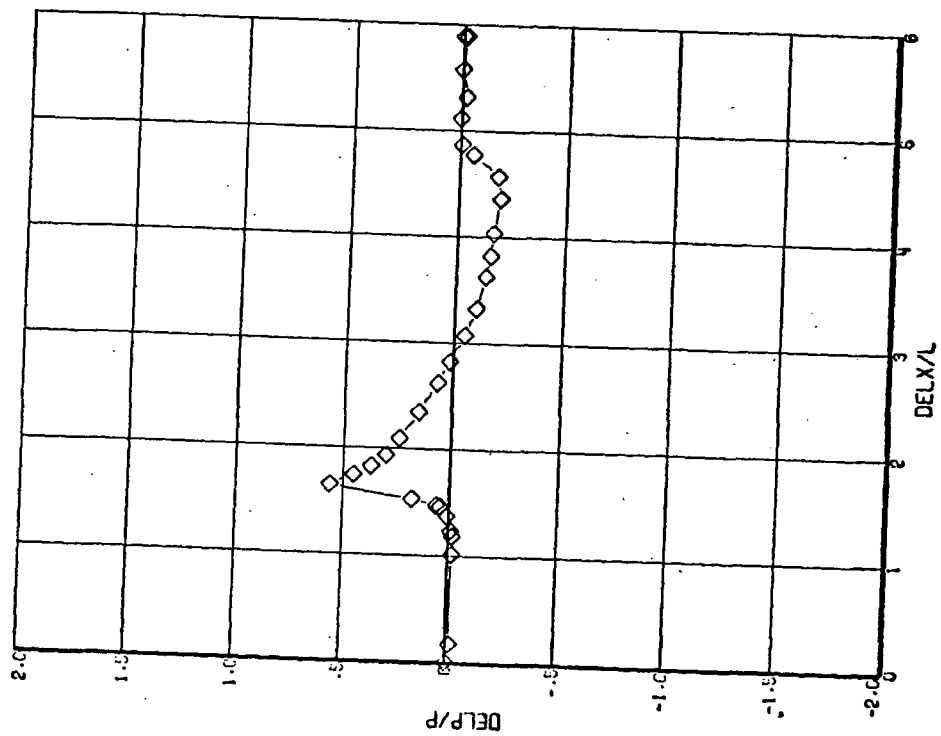
MACH = 3.390 ALPHA = 45.000 PHI = 74.600 W/L = 1.3300

PLOT 70



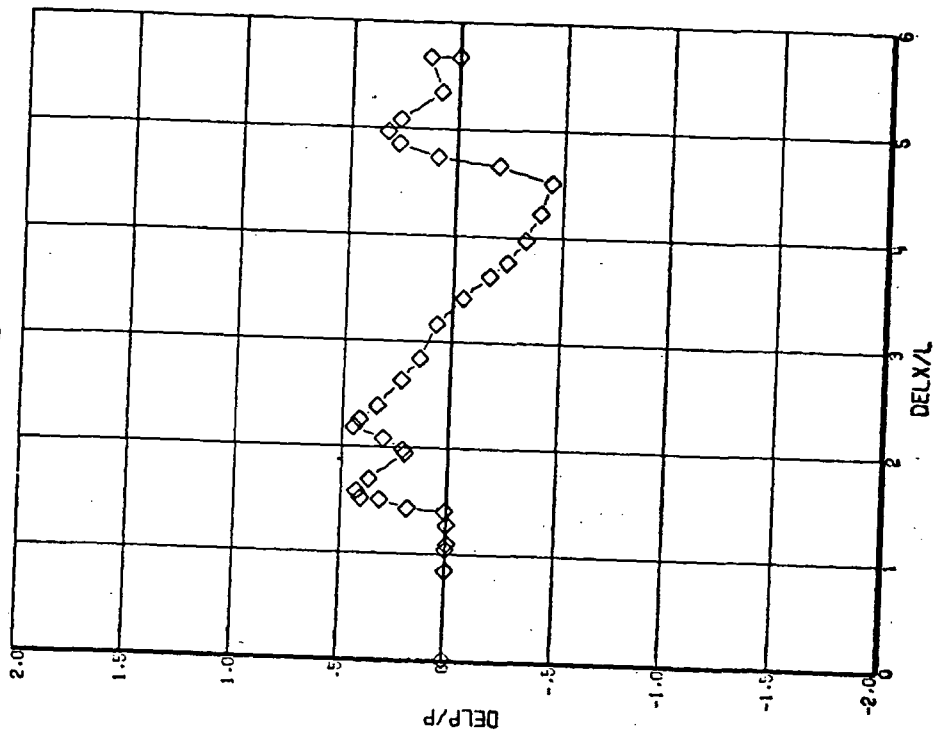
$MACH = 3.980$ $ALPHA = 45.000$ $PHI = 109.100$ $H/L = 1.6200$

PLOT 71



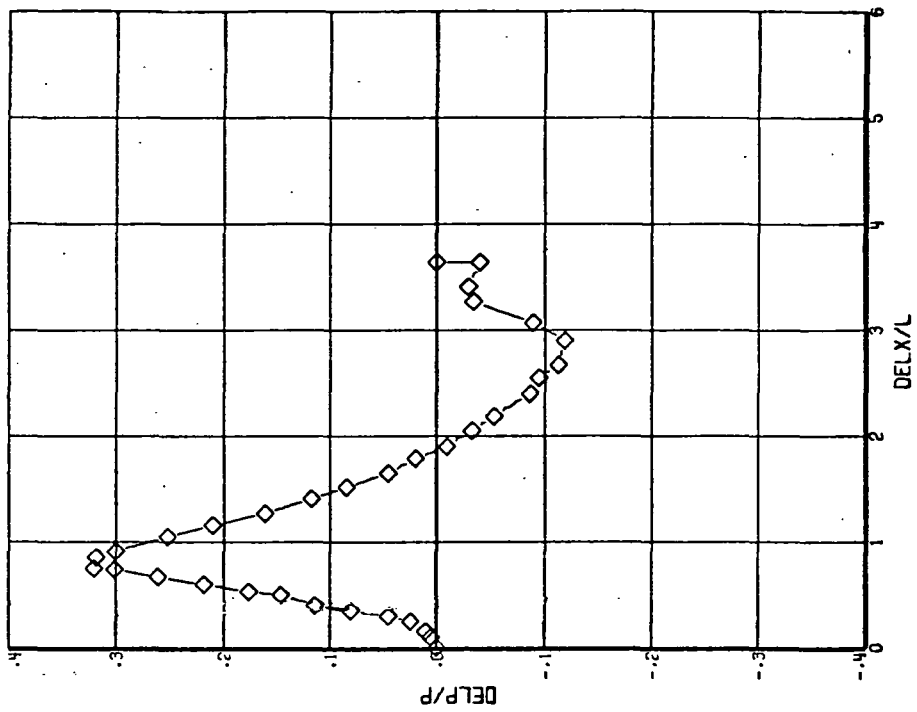
$MACH = 3.980$ $ALPHA = 45.000$ $PHI = 143.200$ $H/L = 1.4800$

PLOT 72



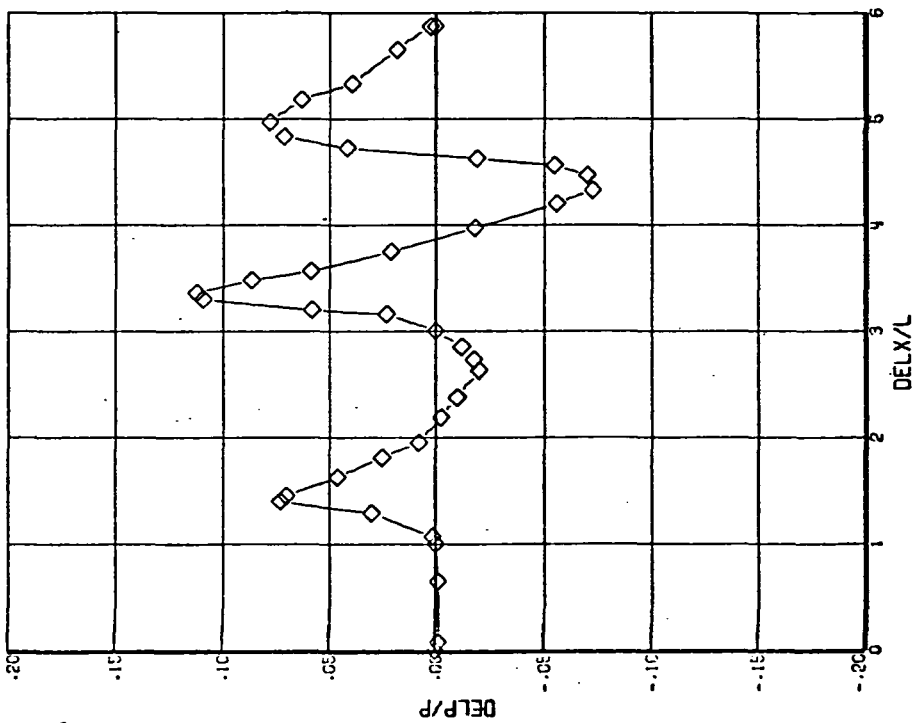
MACH = 5.960 ALPHA = 0.000 PHI = 0.000 W/L = 1.0500

PLOT 74



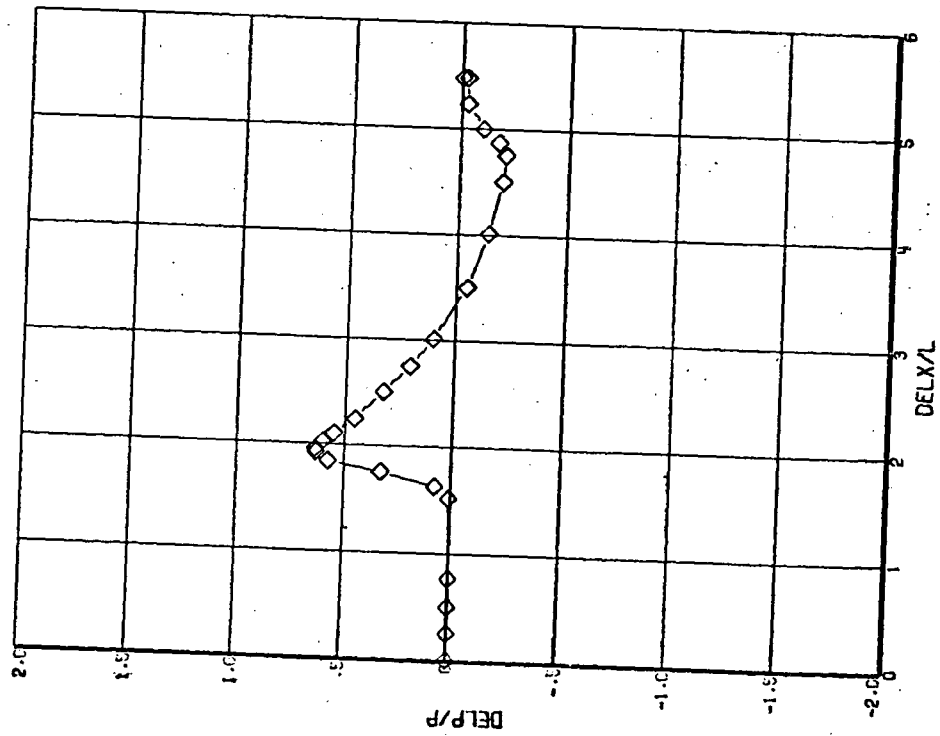
MACH = 3.990 ALPHA = 45.000 PHI = 180.000 W/L = 1.4400

PLOT 73



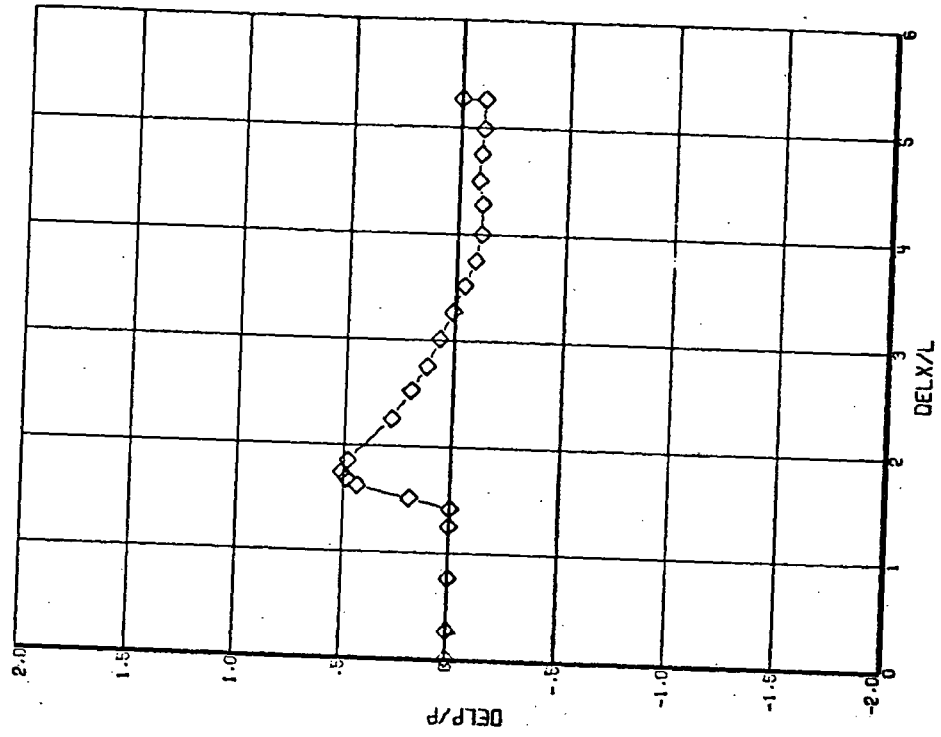
WCH = 5.960 ALPHA = 10.000 PHI = 0.000 W/L = 1.1300

PLOT 75



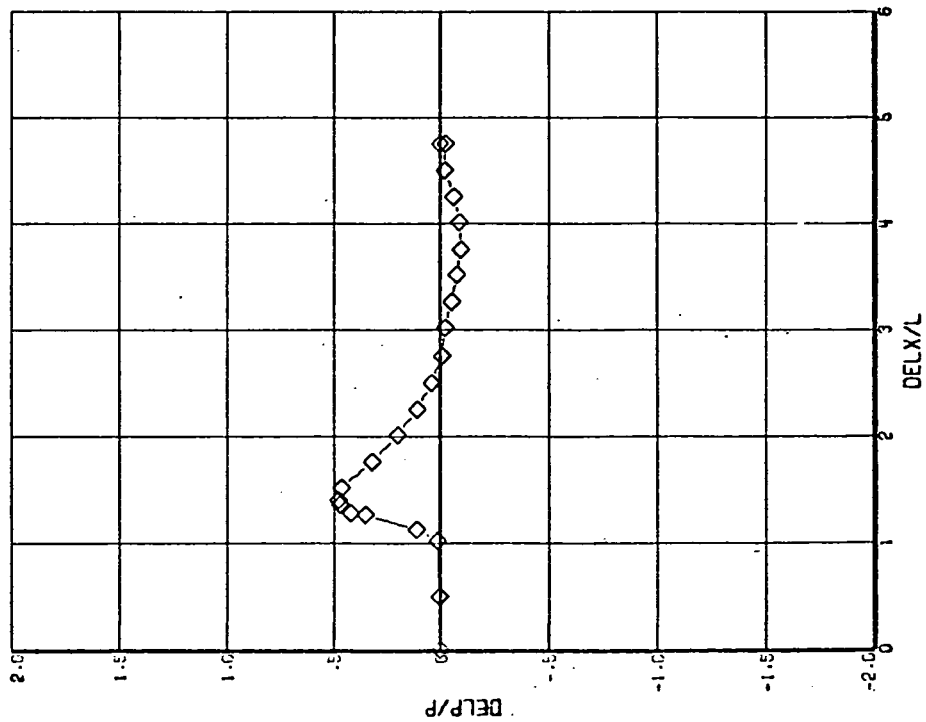
WCH = 5.960 ALPHA = 10.000 PHI = 27.800 W/L = 1.1200

PLOT 76



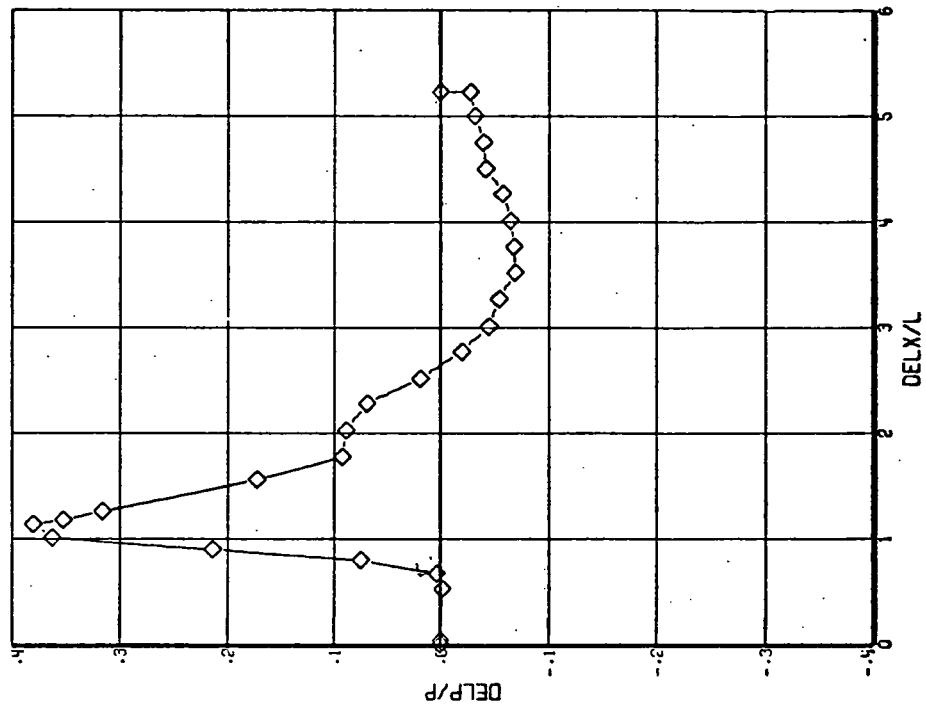
MPCH = 5.960 ALPHA = 10.000 PHI = 56.100 W/L = 1.1000

PLOT 77



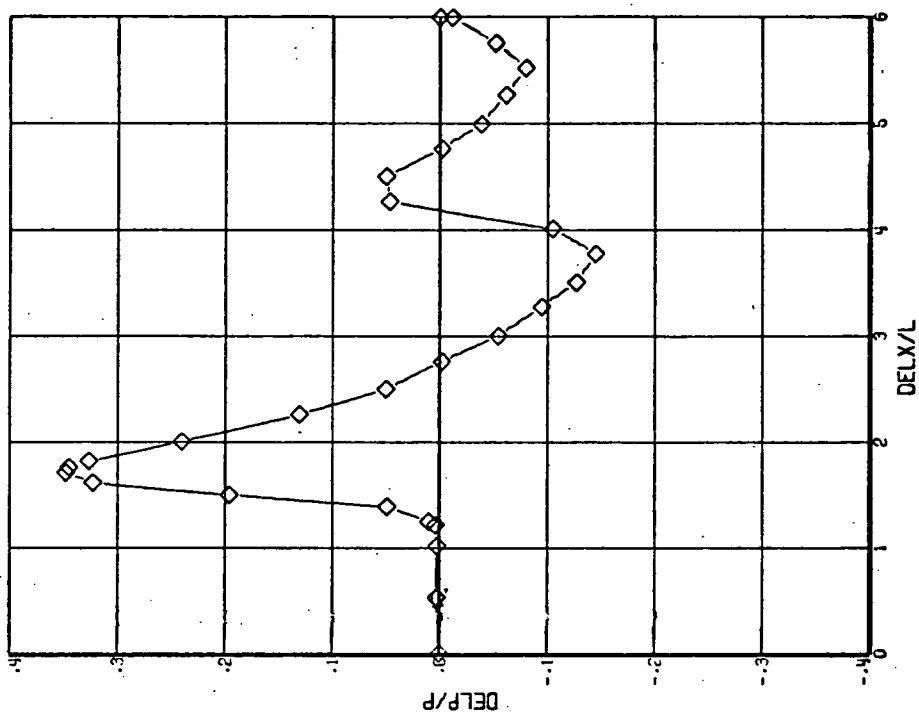
MPCH = 5.960 ALPHA = 10.000 PHI = 86.200 W/L = 1.0500

PLOT 78



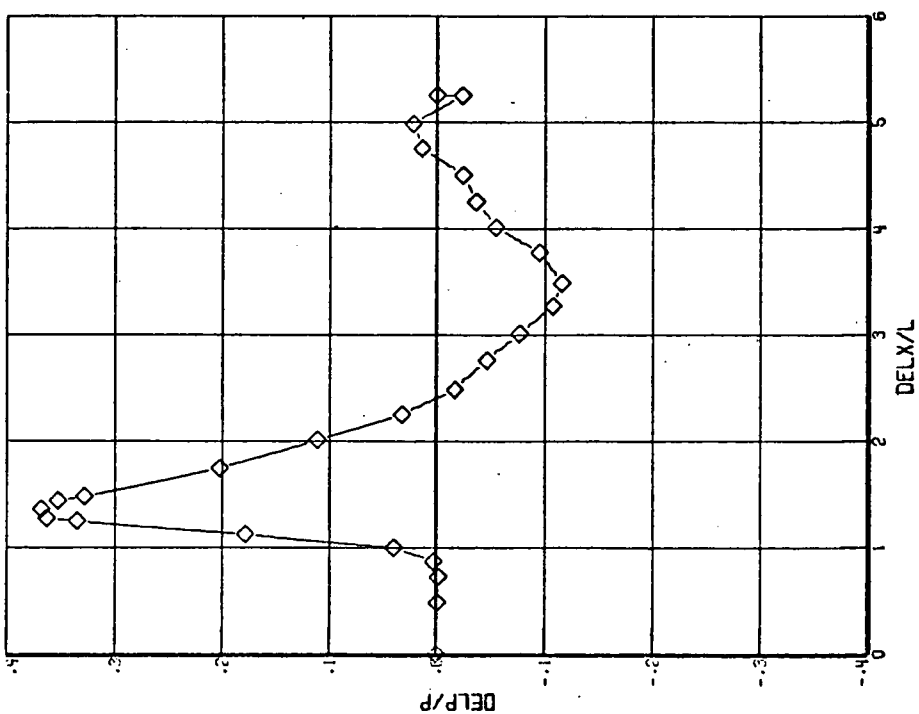
MACH = 5.960 ALPHA = 10.000 PHI = 147.600 H/L = 1.0200

PLOT 80



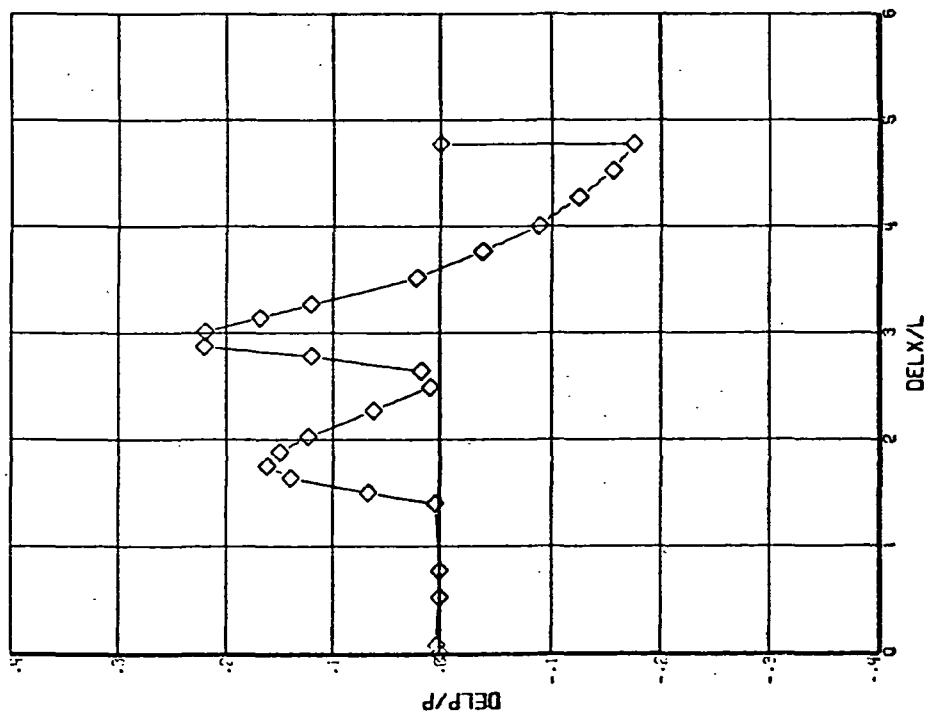
MACH = 5.960 ALPHA = 10.000 PHI = 115.800 H/L = 1.0300

PLOT 79



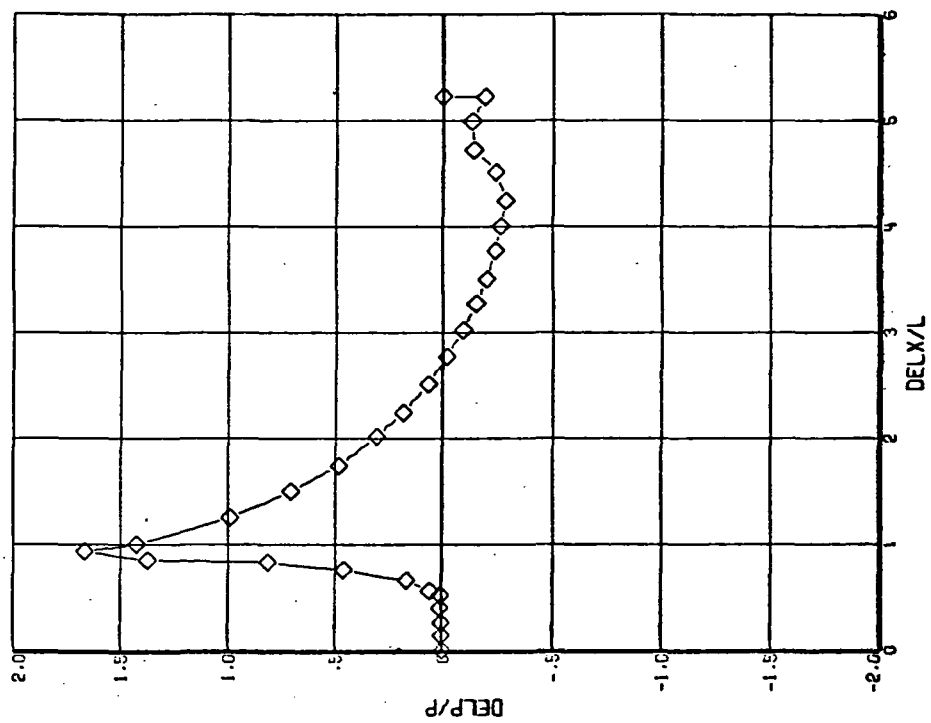
$\mu_{CH} = 5.960$ $\alpha_{PHA} = 10.000$ $\phi_{HI} = 180.000$ $\mu/L = 1.0100$

PLOT 81



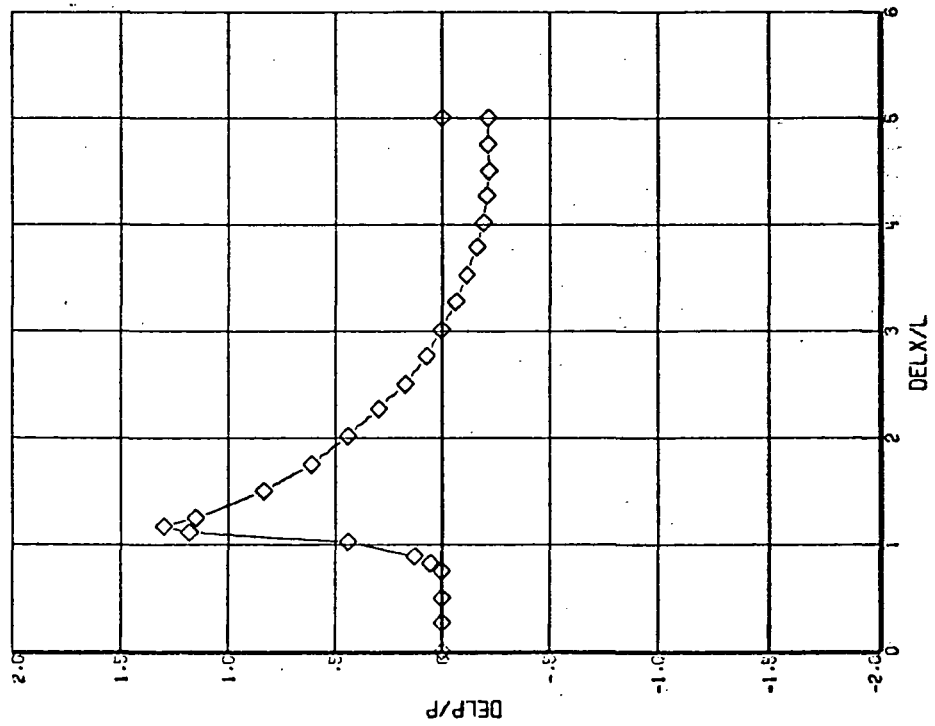
$\mu_{CH} = 5.960$ $\alpha_{PHA} = 25.000$ $\phi_{HI} = 0.000$ $\mu/L = 1.2600$

PLOT 82



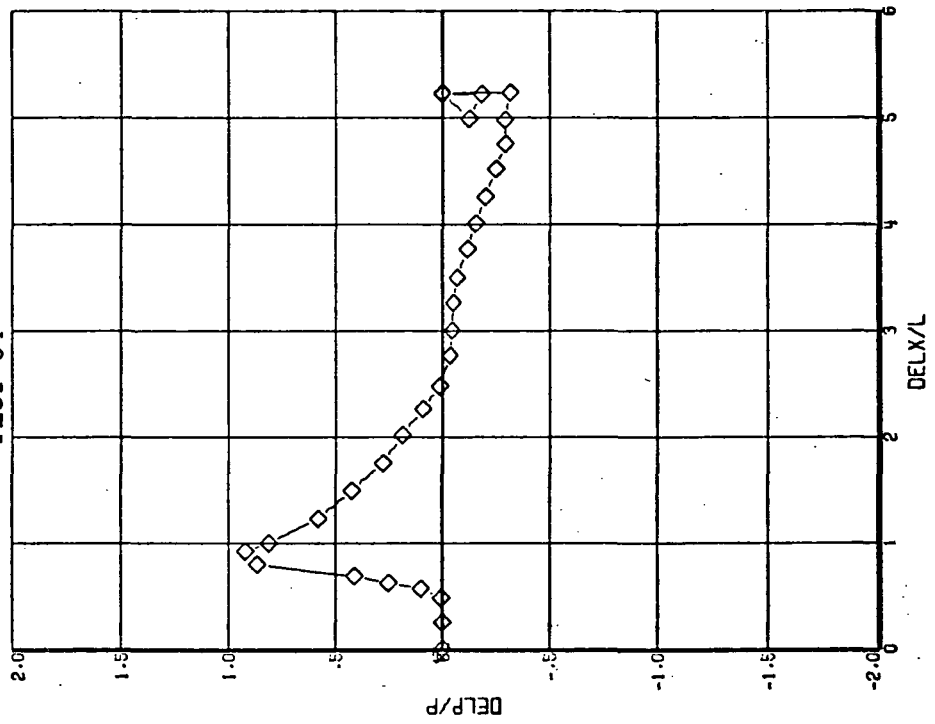
MACH = 5.960 ALPHA = 25.000 PHI = 25.100 H/L = 1.7400

PLOT 83



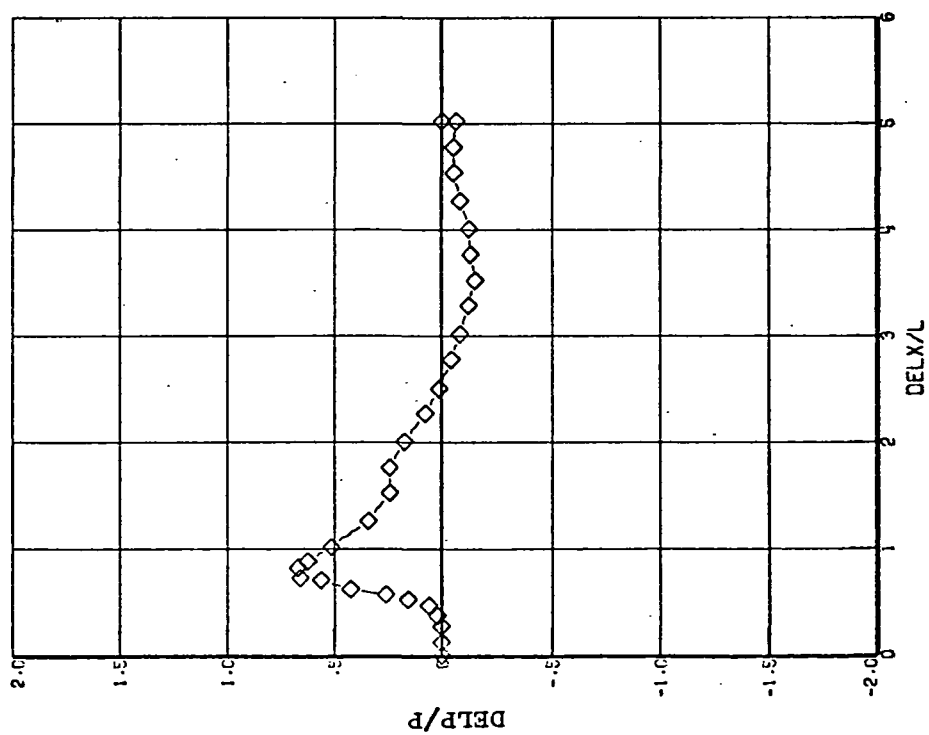
MACH = 5.960 ALPHA = 25.000 PHI = 51.100 H/L = 1.1800

PLOT 84



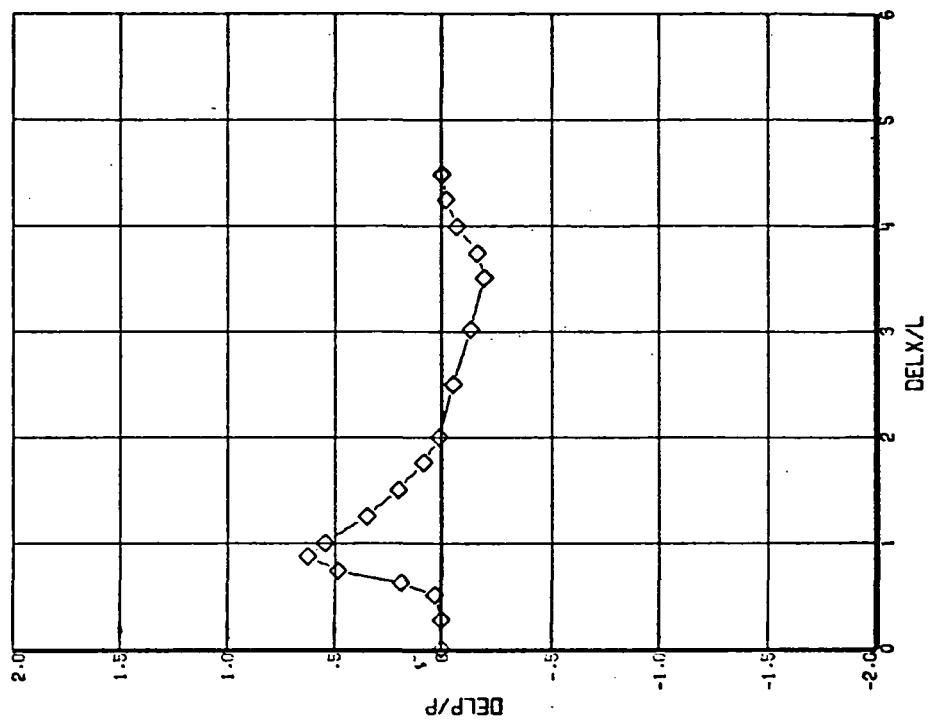
MACH = 5.960 ALPHA = 25.000 PHI = 78.600 W/L = 1.0700

PLOT 85



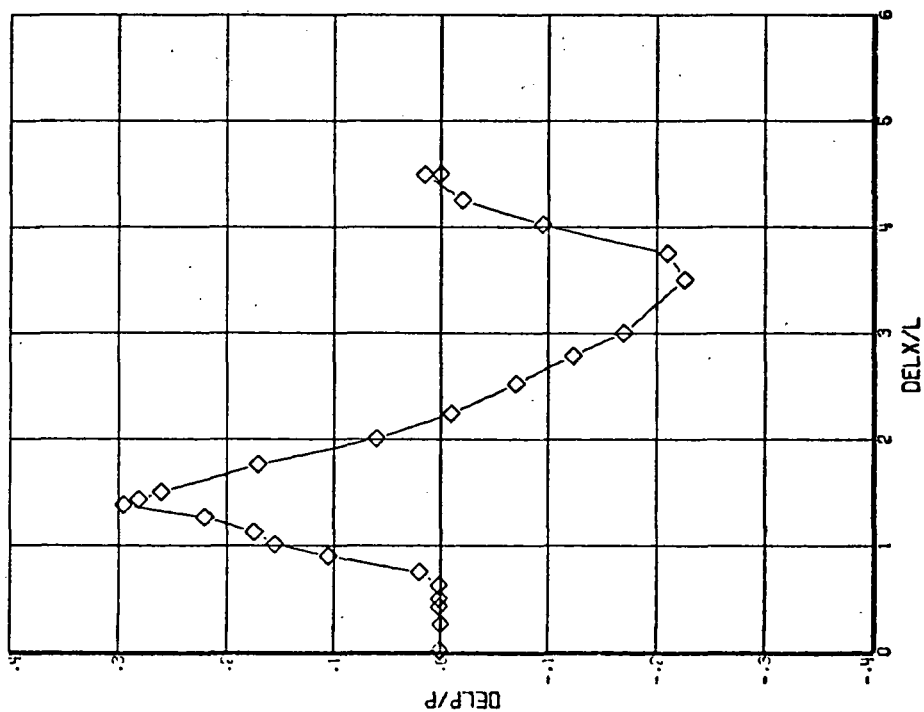
MACH = 5.960 ALPHA = 25.000 PHI = 109.500 W/L = 1.0000

PLOT 86



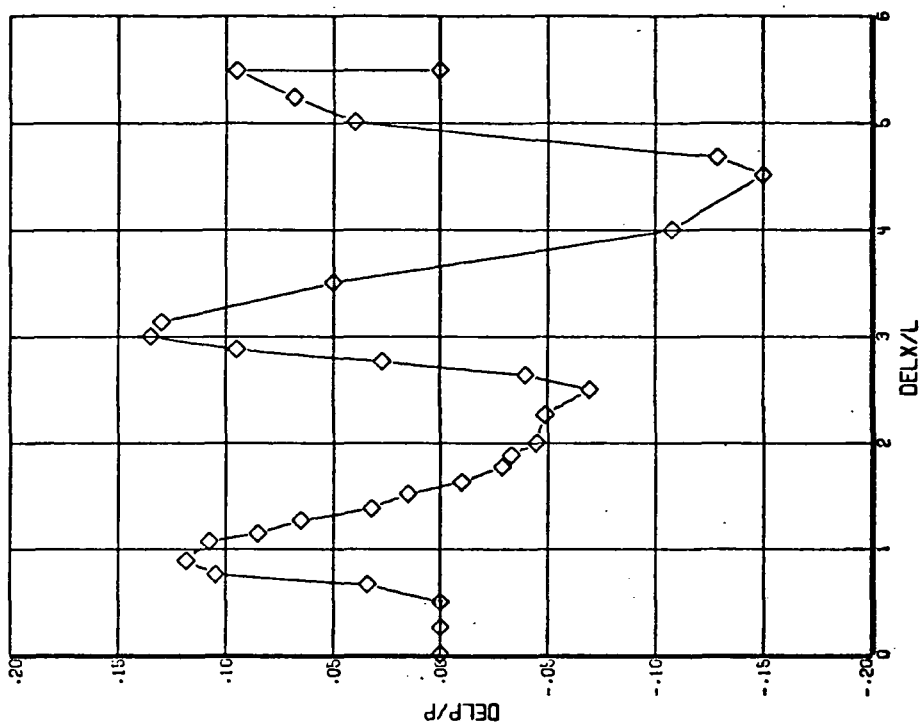
MACH = 5.960 ALPMA = 25.000 PHI = 143.500 H/L = .9300

PLOT 87



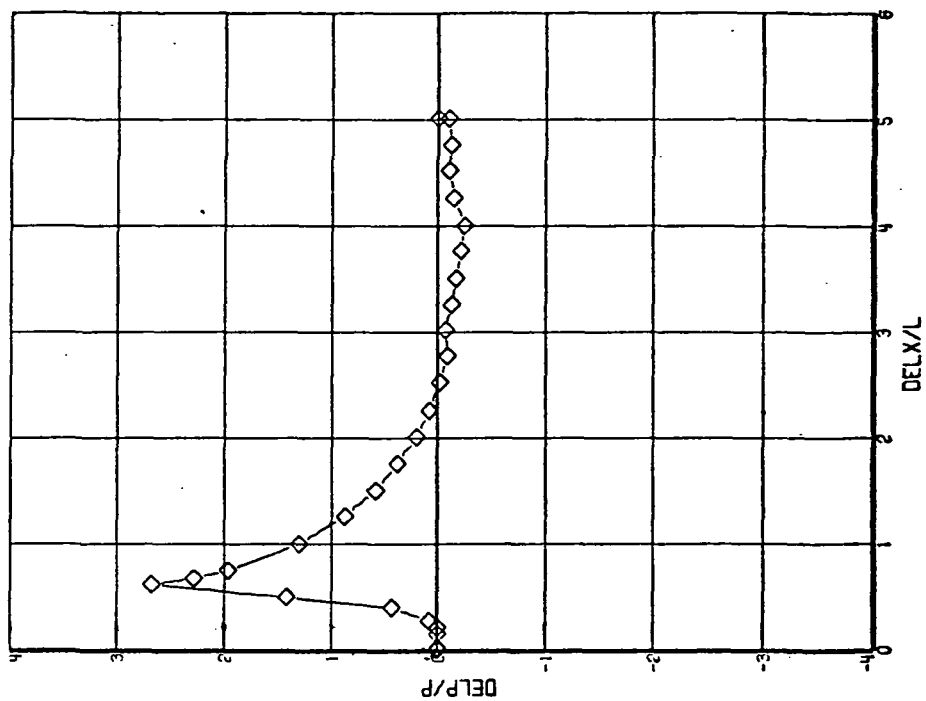
MACH = 5.960 ALPMA = 25.000 PHI = 180.000 H/L = .8800

PLOT 88



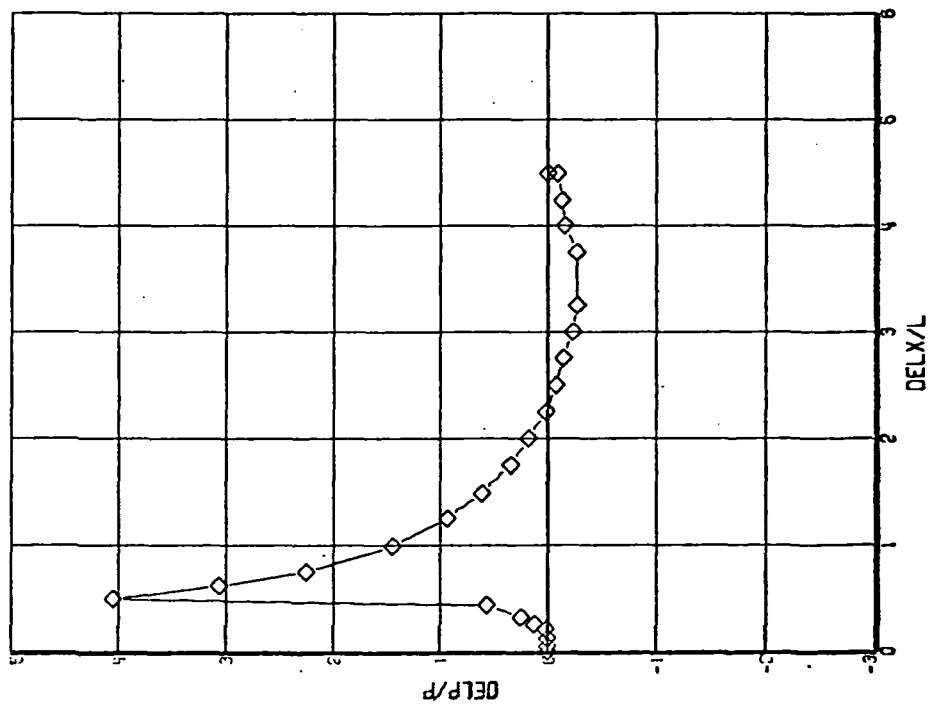
$\mu_{CH} = 5.960$ $\alpha_{PWA} = 45.000$ $\phi_i = 22.400$ $H/L = 1.3400$

PLOT 90



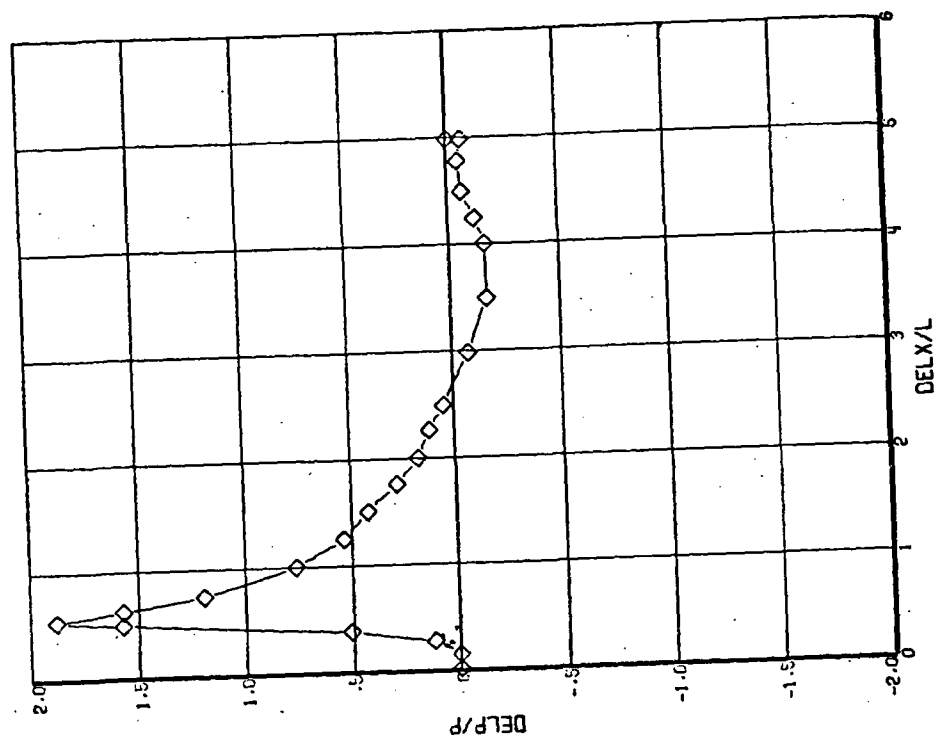
$\mu_{CH} = 5.960$ $\alpha_{PWA} = 45.000$ $\phi_i = 0.000$ $H/L = 1.3800$

PLOT 89



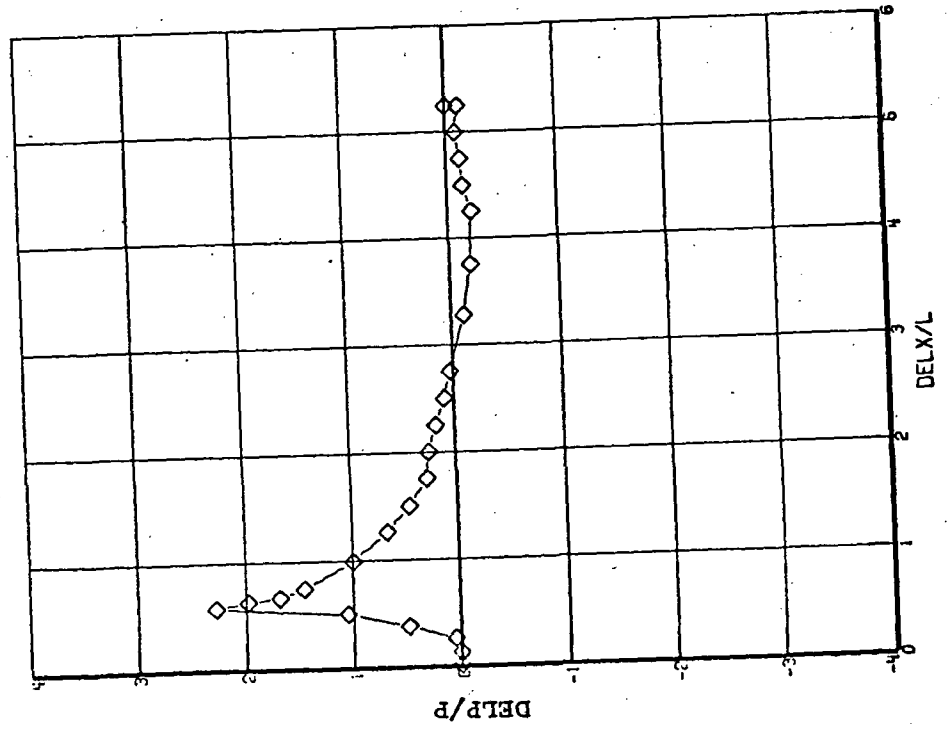
$\mu_{CH} = 5.960$ $\alpha_{PHA} = 45.000$ $\phi_{H1} = 70.800$ $\mu/L = 1.0800$

PLOT 92



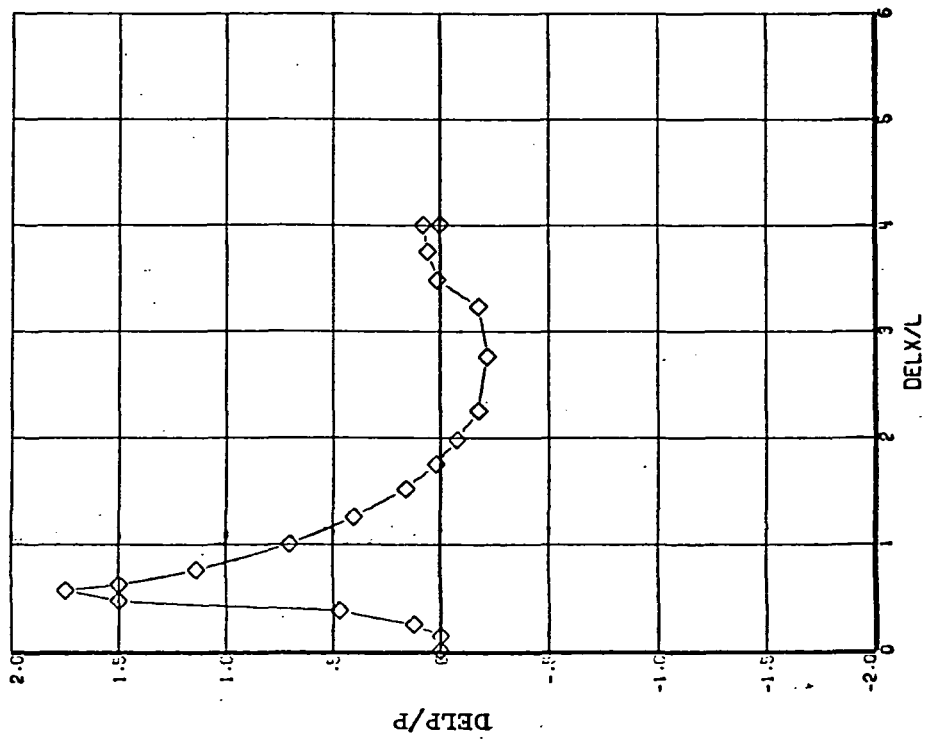
$\mu_{CH} = 5.960$ $\alpha_{PHA} = 45.000$ $\phi_{H1} = 45.500$ $\mu/L = 1.2200$

PLOT 91



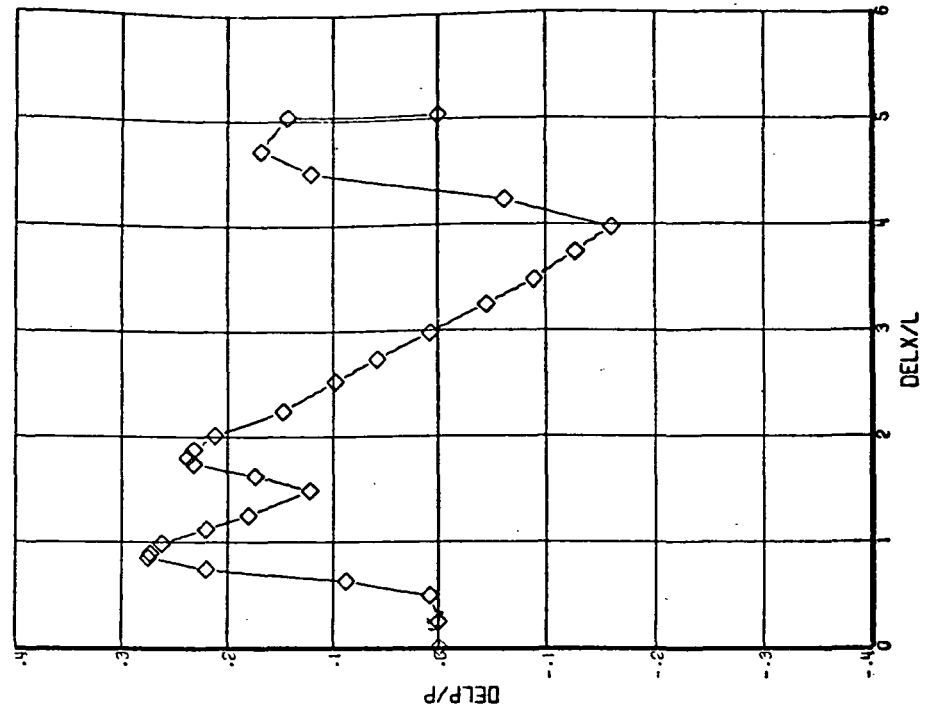
MACH = 5.960 ALPHA = 46.000 PHI = 100.400 H/L = .9100

PLOT 93



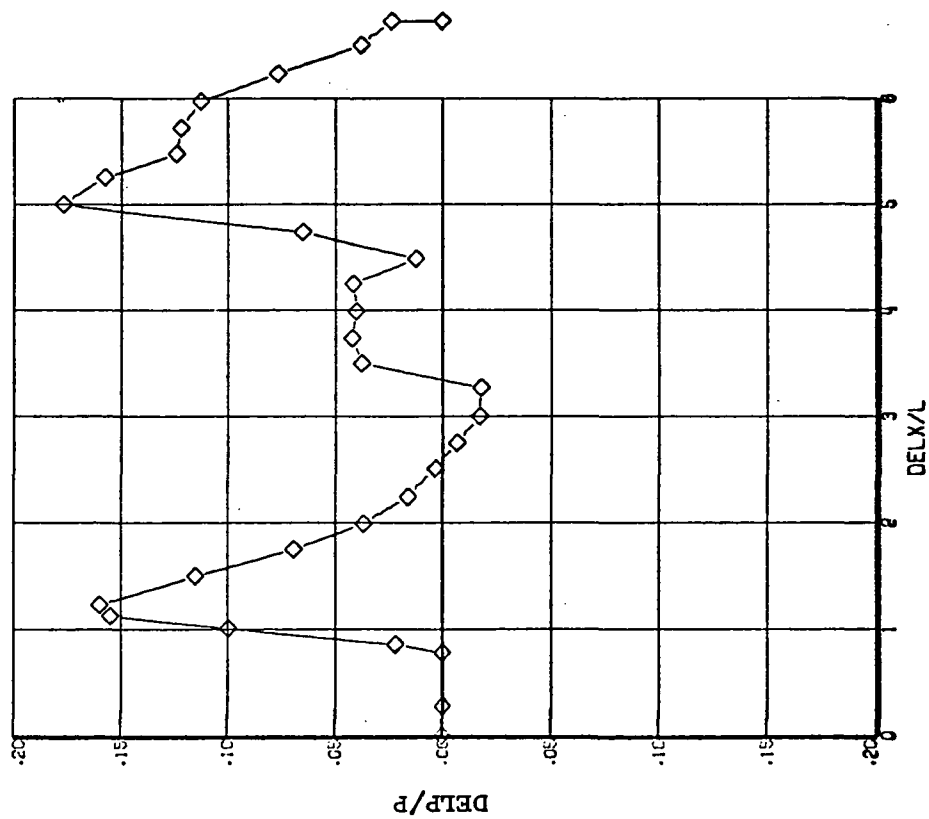
MACH = 5.960 ALPHA = 46.000 PHI = 134.900 H/L = 1.0000

PLOT 94



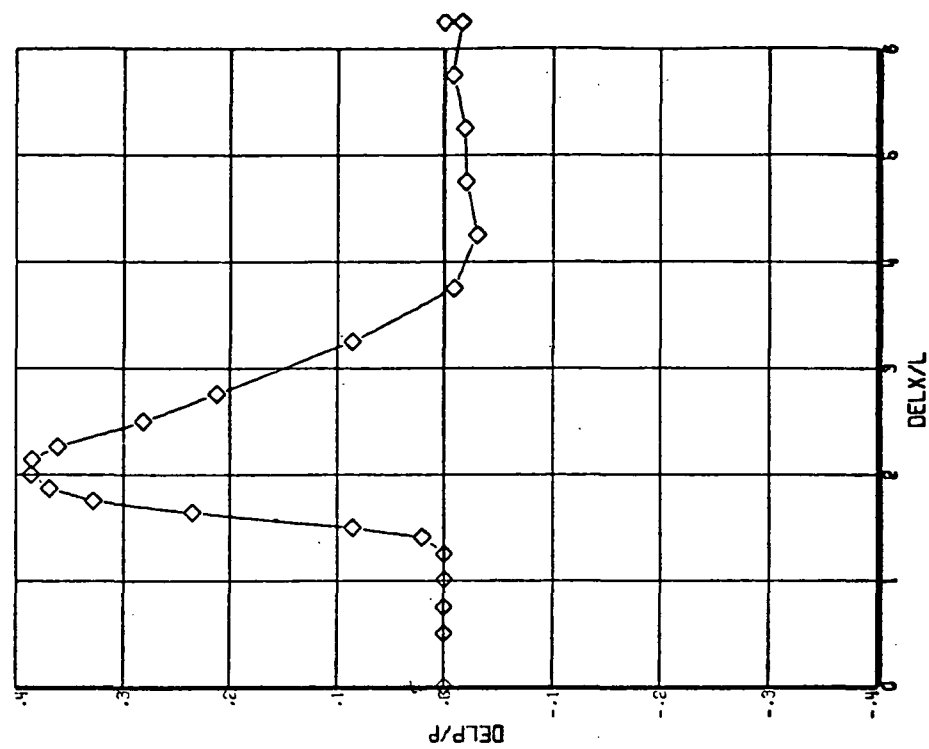
PROCH = 5.360 ALPHA = 45.000 PHI = 180.000 H/L = .3500

PLOT 95



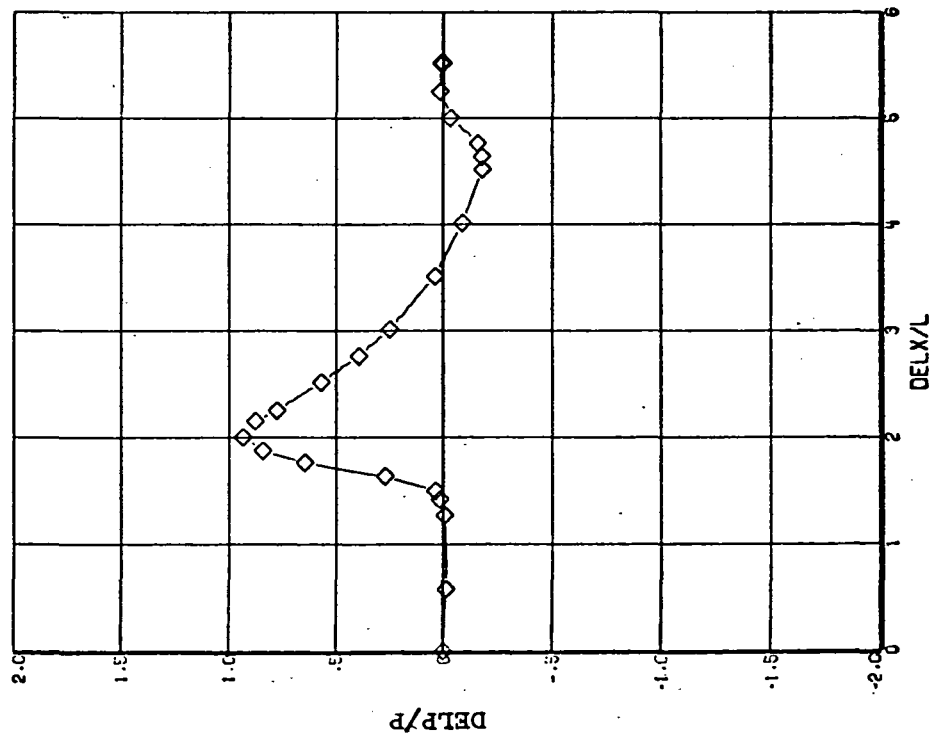
PROCH = 7.750 ALPHA = 0.000 PHI = 0.000 H/L = 1.0500

PLOT 96



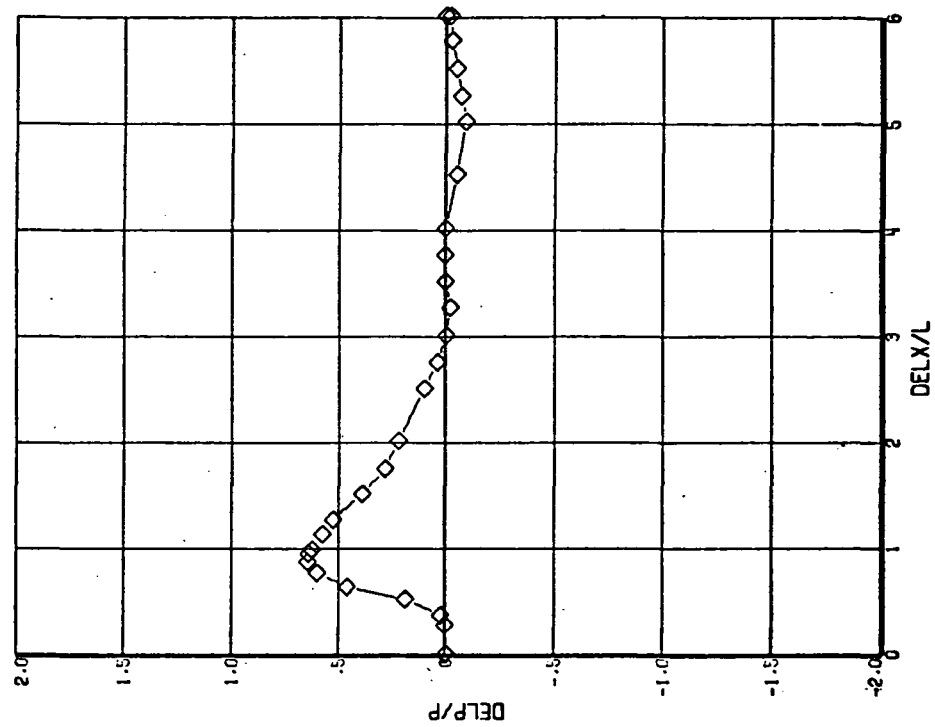
$\text{MACH} = 7.750$
 $\text{ALPHA} = 10.000$
 $\text{PHI} = 0.000$
 $\text{W/L} = 1.0400$

PLOT 97



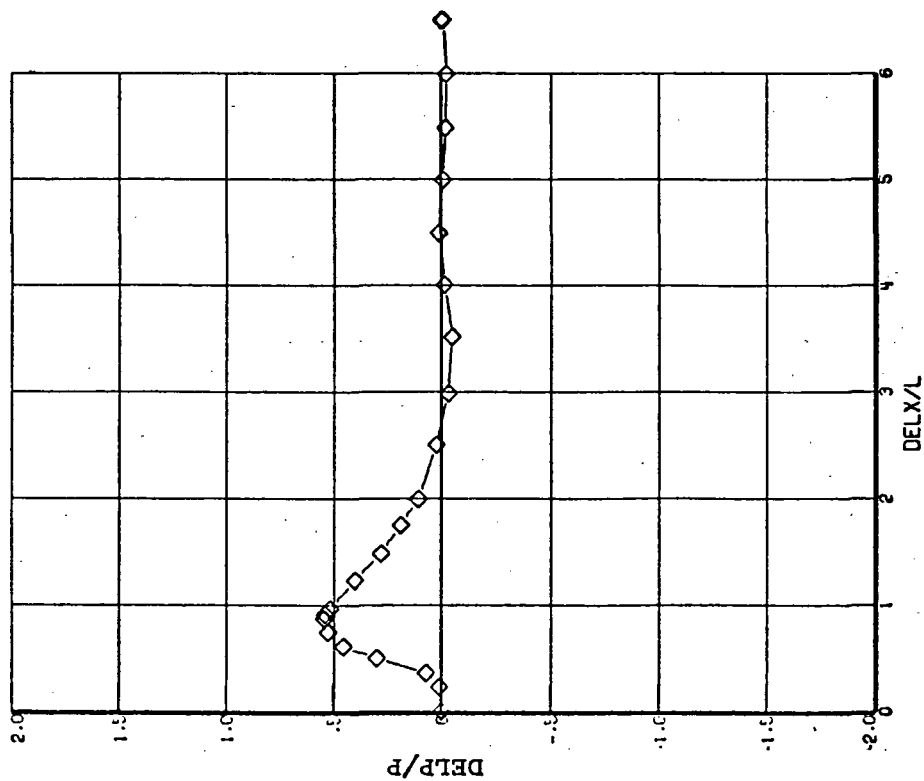
$\text{MACH} = 7.750$
 $\text{ALPHA} = 10.000$
 $\text{PHI} = 27.700$
 $\text{W/L} = 1.0500$

PLOT 98



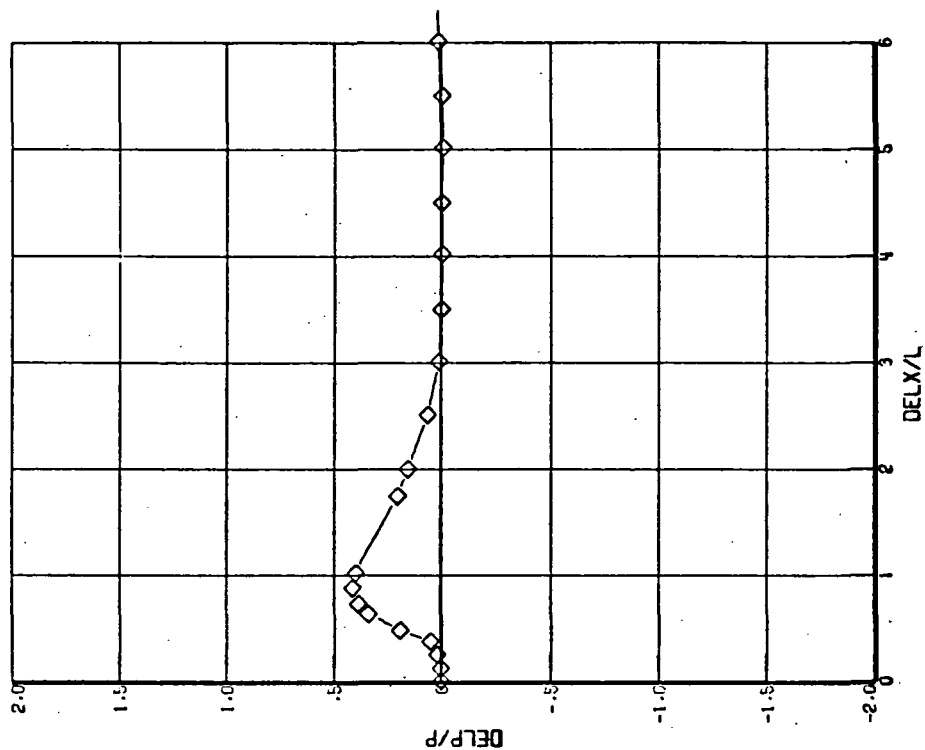
MACH = 7.750 ALPHA = 10.000 PHI = 56.200 H/L = 1.1300

PLOT 99



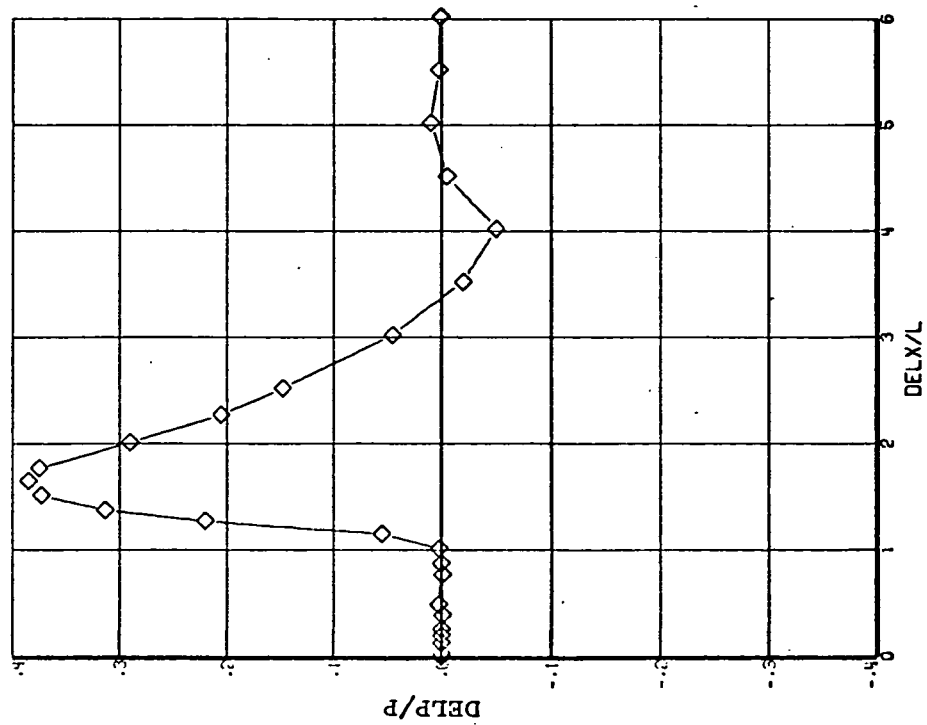
MACH = 7.750 ALPHA = 10.000 PHI = 85.700 H/L = 1.1600

PLOT 100



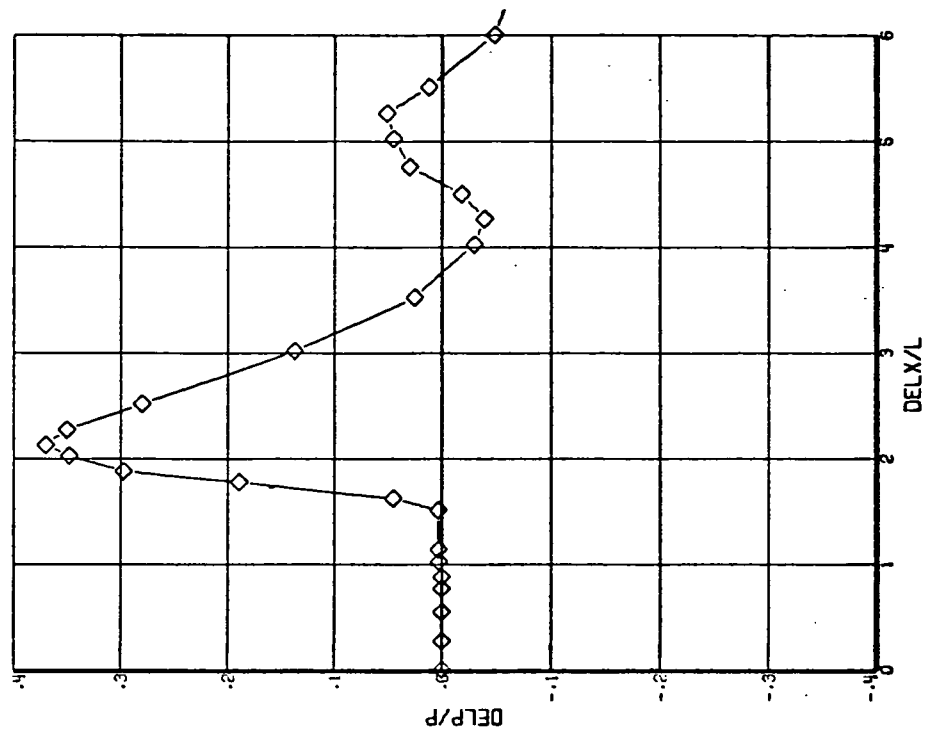
$MACH = 7.750$ $ALPHA = 10.000$ $PHI = 1.16400$ $H/L = 1.2100$

PLOT 101



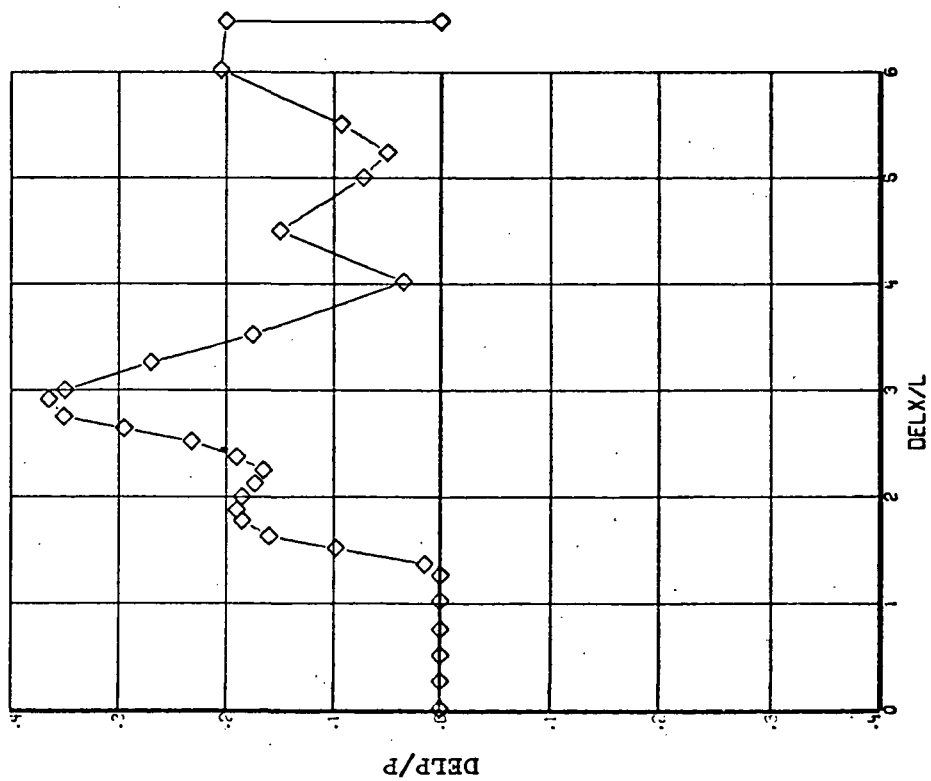
$MACH = 7.750$ $ALPHA = 10.000$ $PHI = 1.147300$ $H/L = 1.1900$

PLOT 102



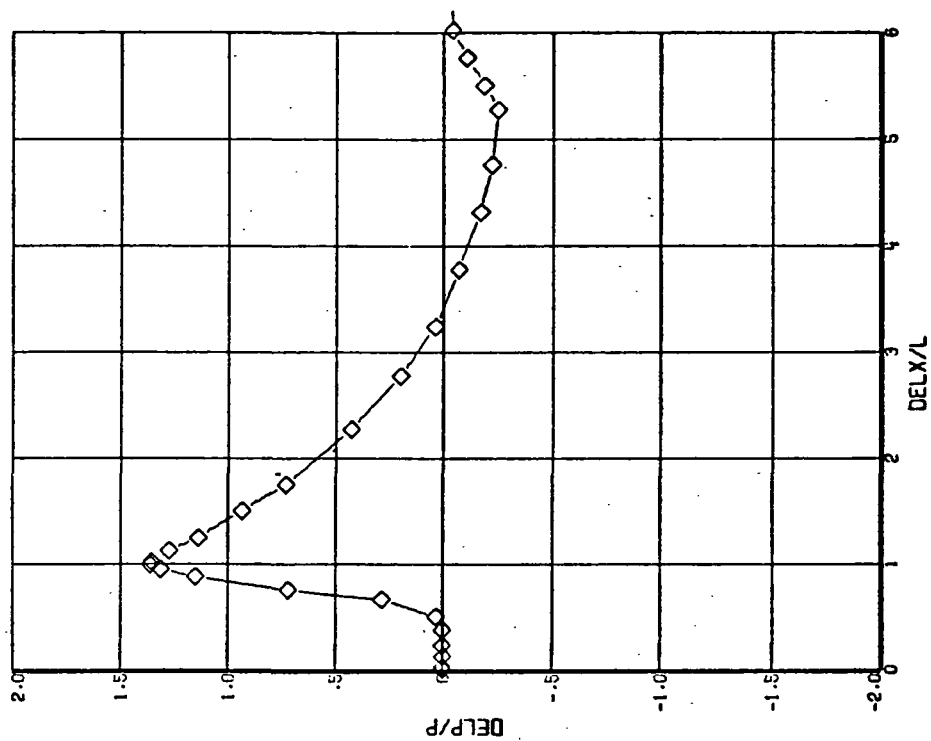
MACH = 7.750 ALPHA = 10.000 PHI = 180.000 H/L = 1.1200

PLOT 103



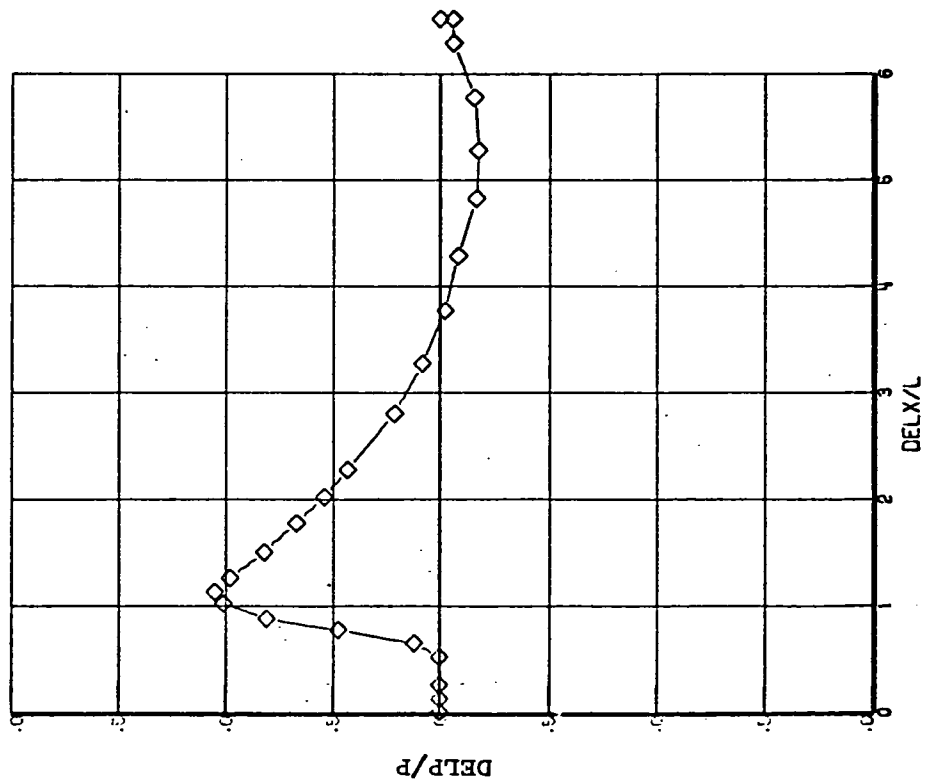
MACH = 7.750 ALPHA = 25.000 PHI = 0.000 H/L = 1.4900

PLOT 104



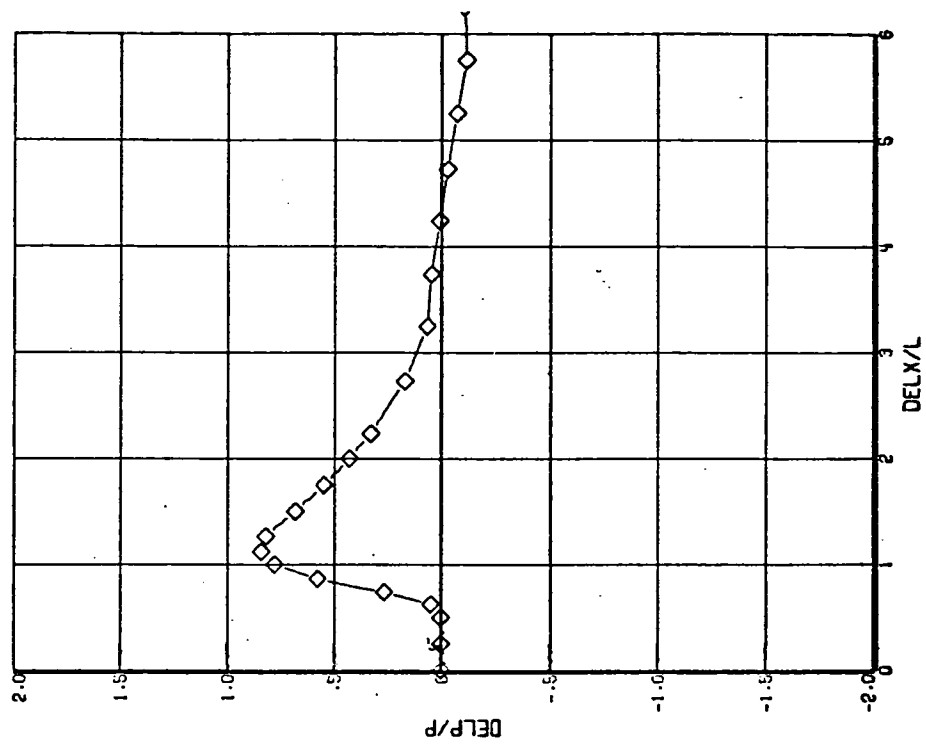
MRCH = 7.750 ALPHA = 25.000 PHI = 25.900 M/L = 1.4600

PLOT 105



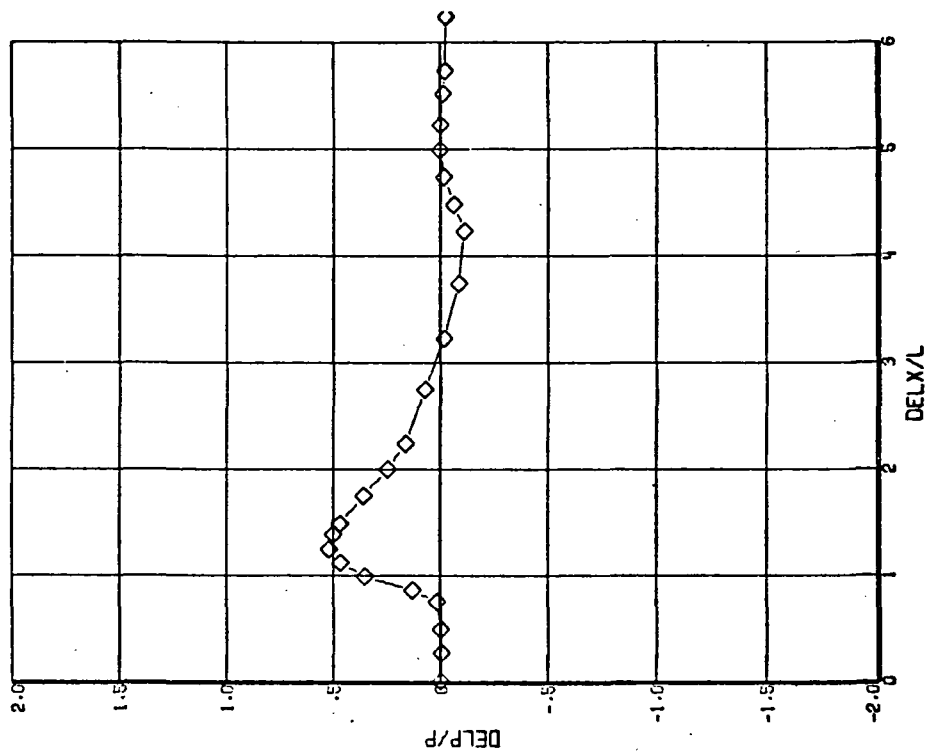
MRCH = 7.750 ALPHA = 25.000 PHI = 52.500 M/L = 1.4100

PLOT 106



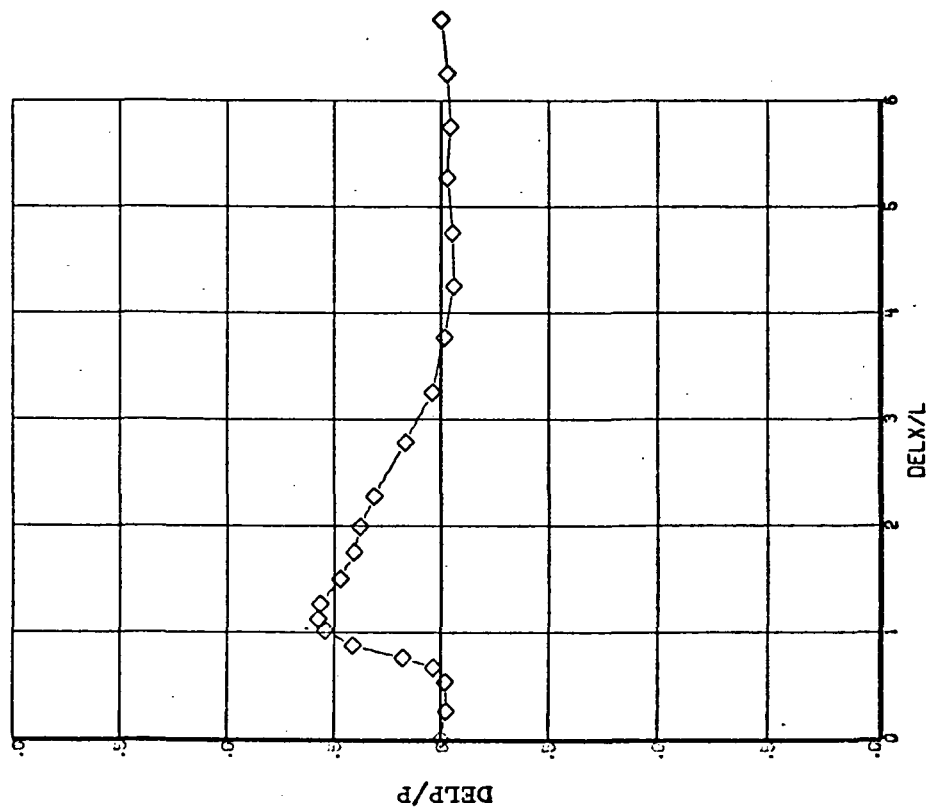
MSCH = 7.750 ALPHA = 25.000 PHI = 111.400 H/L = 1.2200

PLOT 108



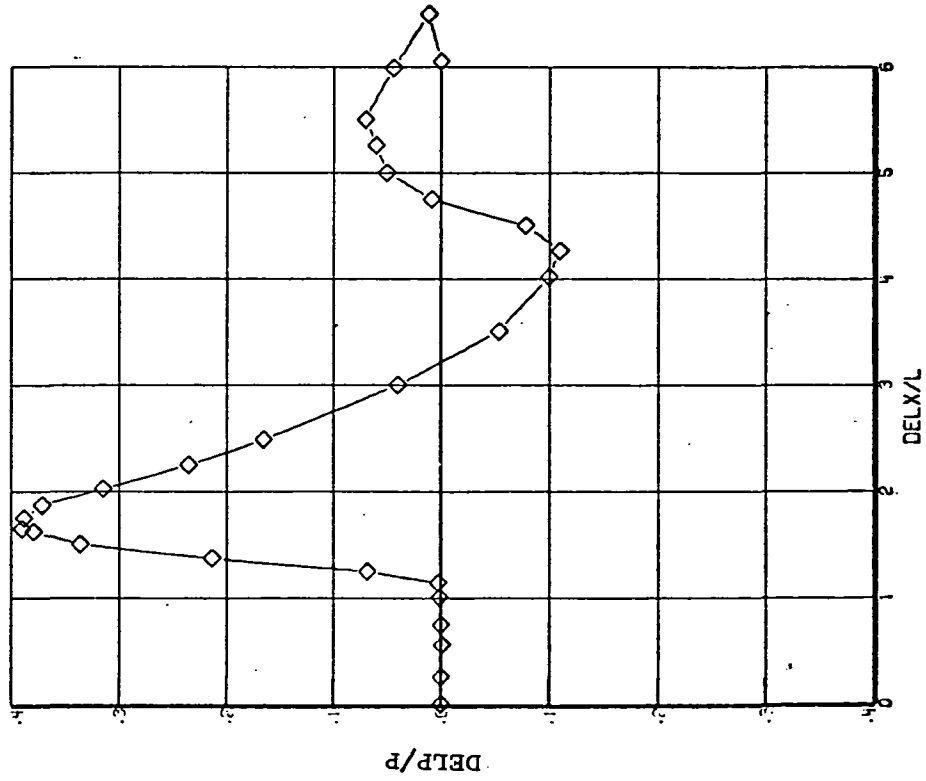
MSCH = 7.750 ALPHA = 25.000 PHI = 80.500 H/L = 1.3300

PLOT 107



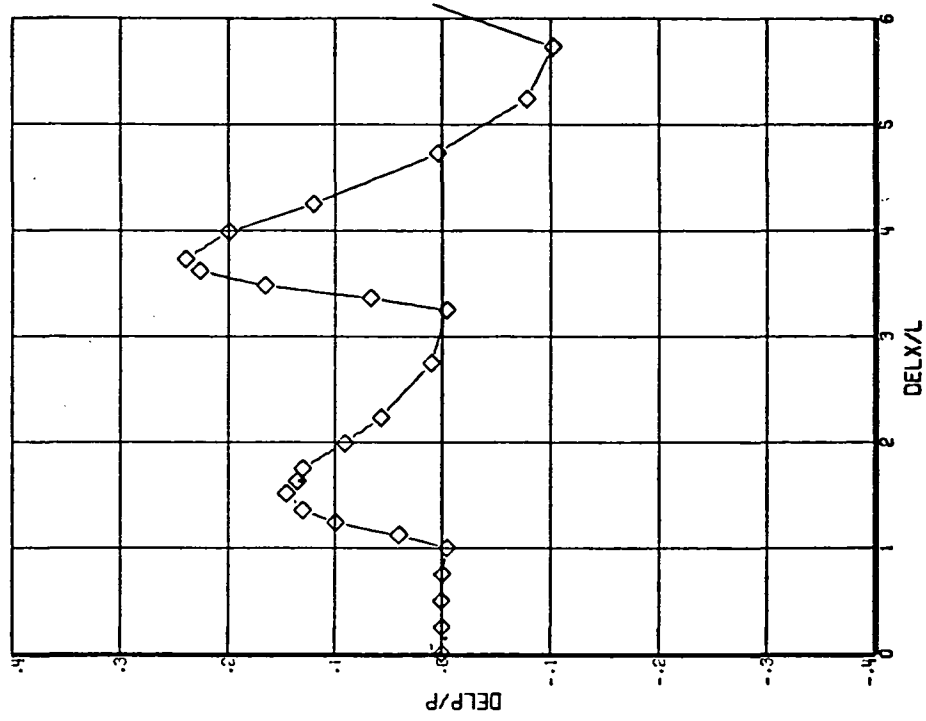
$\text{MACH} = 7.750$ $\text{ALPHA} = 25.000$ $\text{PHI} = 144.700$ $\text{H/L} = 1.1500$

PLOT 109



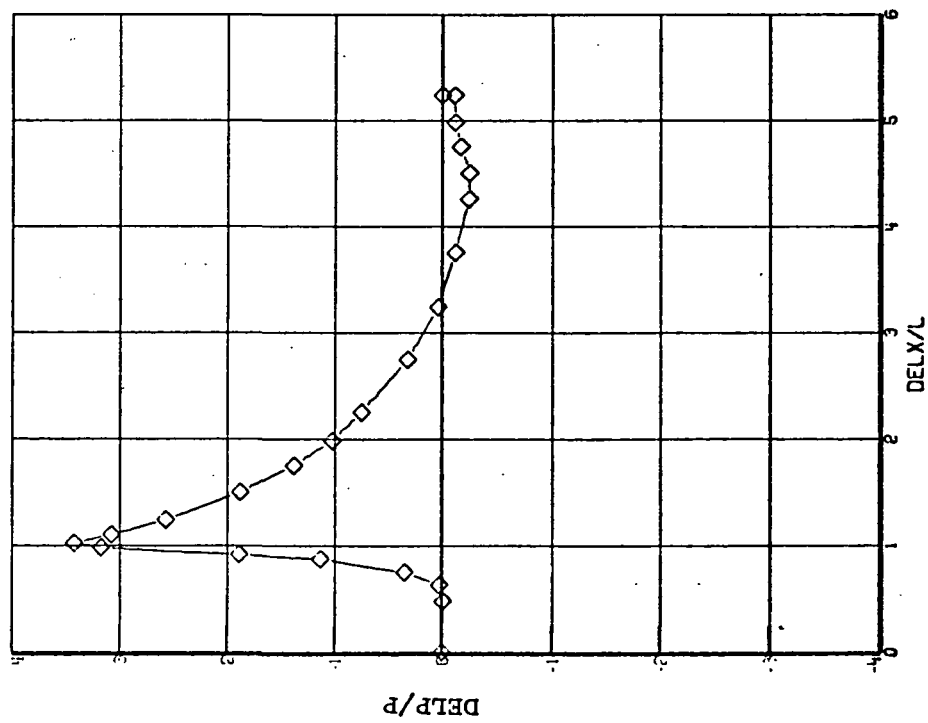
$\text{MACH} = 7.750$ $\text{ALPHA} = 25.000$ $\text{PHI} = 180.000$ $\text{H/L} = 1.1200$

PLOT 110



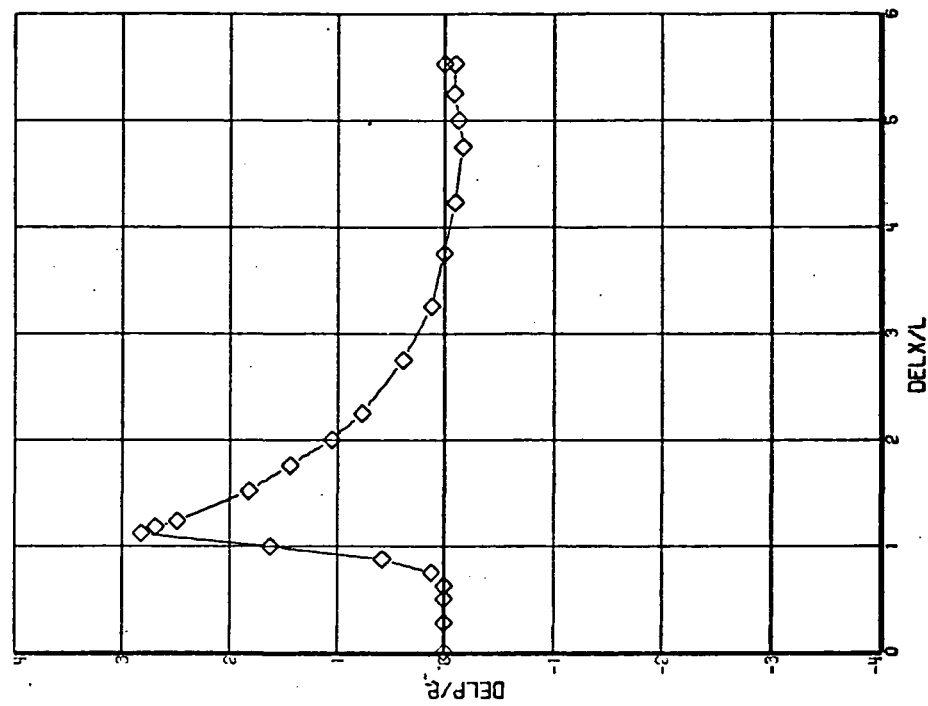
MACH = 7.750 ALPHA = 45.000 PHI = 0.000 H/L = 1.6200

PLOT 111



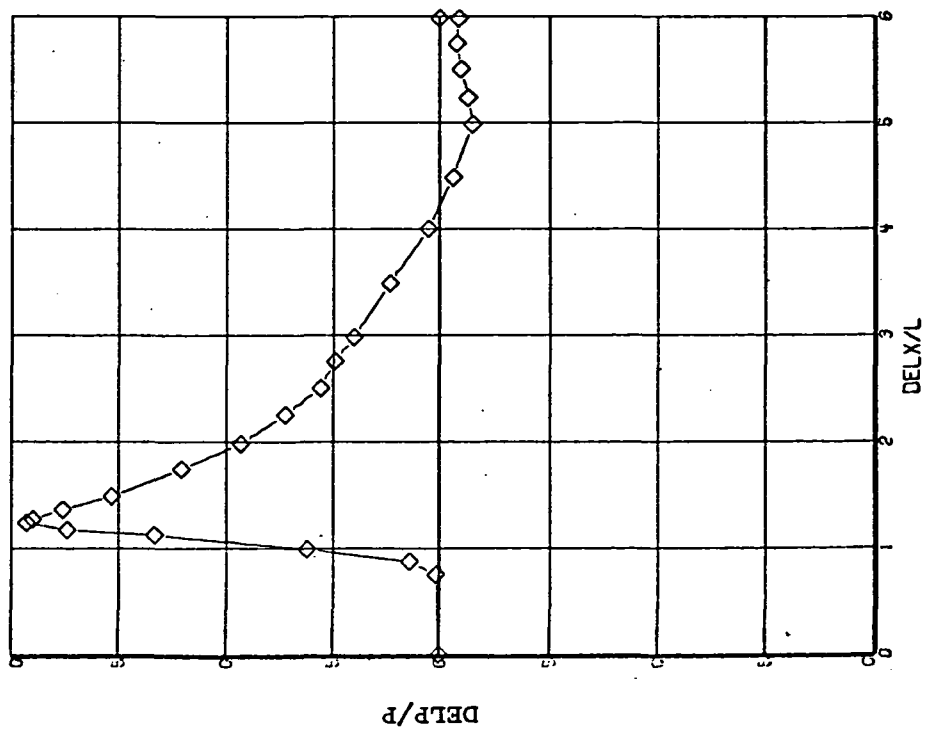
MACH = 7.750 ALPHA = 45.000 PHI = 23.600 H/L = 1.6800

PLOT 112



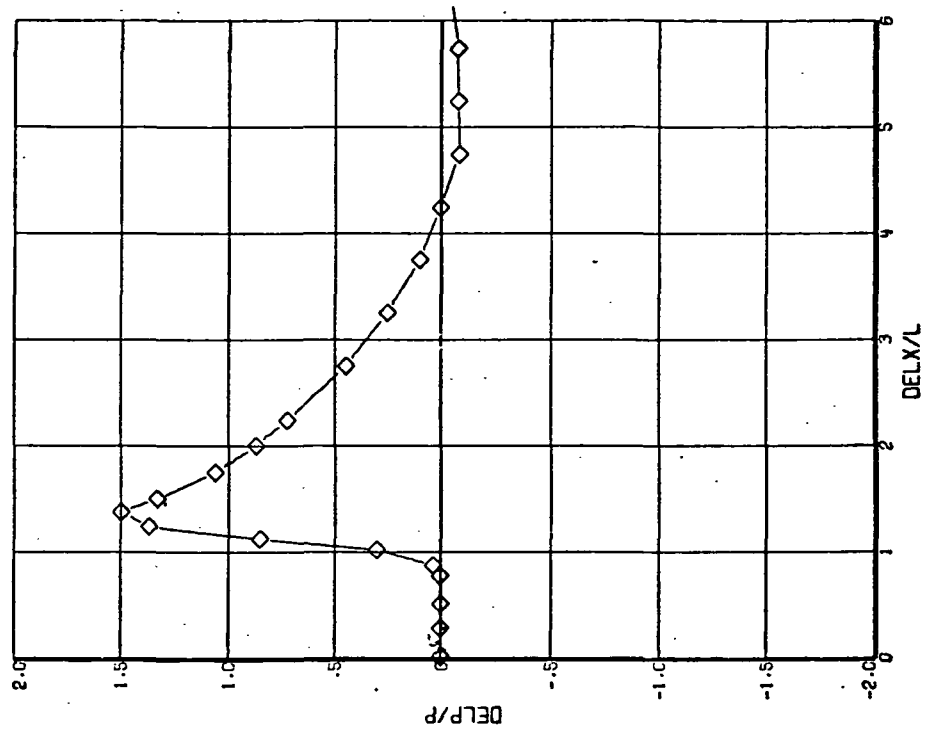
PRCH = 7.750 ALPHA = 45.000 PHI = 48.000 H/L = 1.4700

PLOT 113



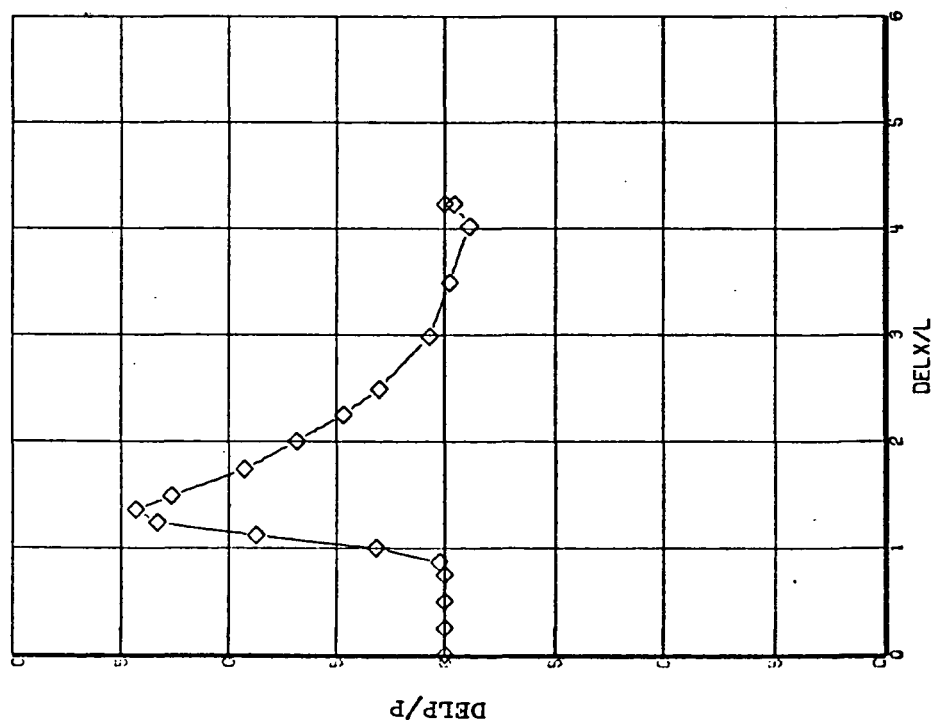
PRCH = 7.750 ALPHA = 45.000 PHI = 74.600 H/L = 1.3300

PLOT 114



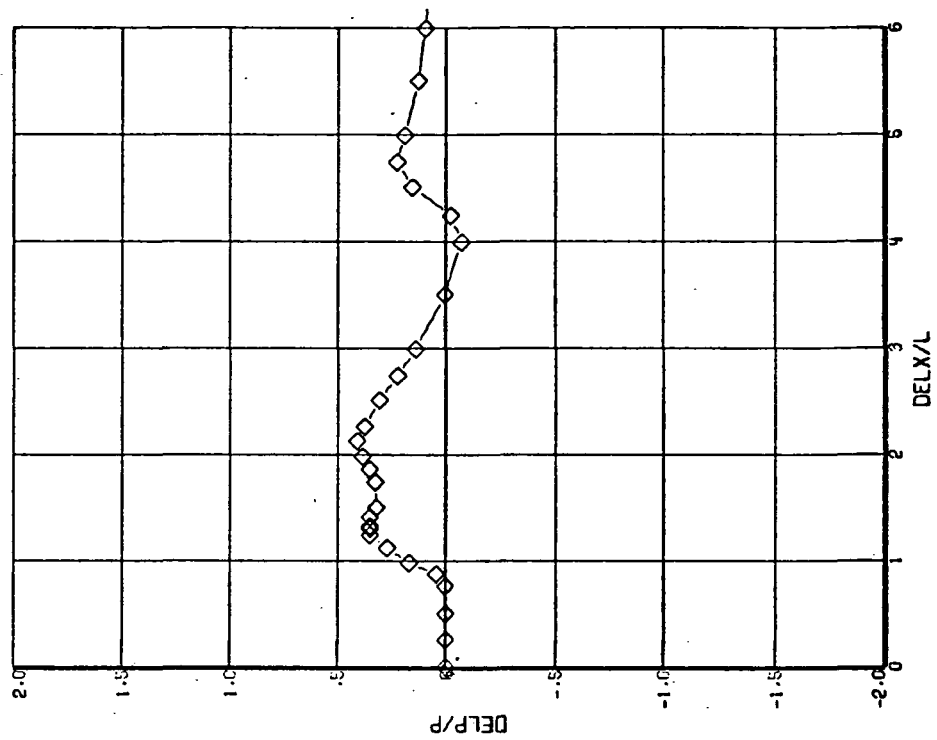
MECH = 7.750 ALPHA = 45.000 PHI = 104.600 H/L = 1.1500

PLOT 115



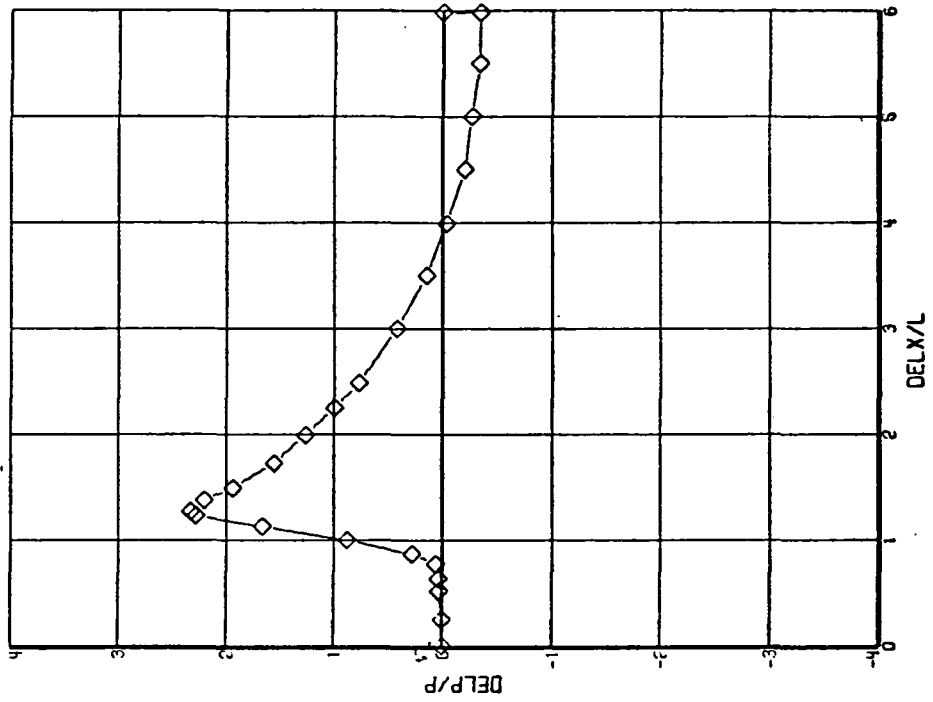
MECH = 7.750 ALPHA = 45.000 PHI = 139.800 H/L = 1.0000

PLOT 116



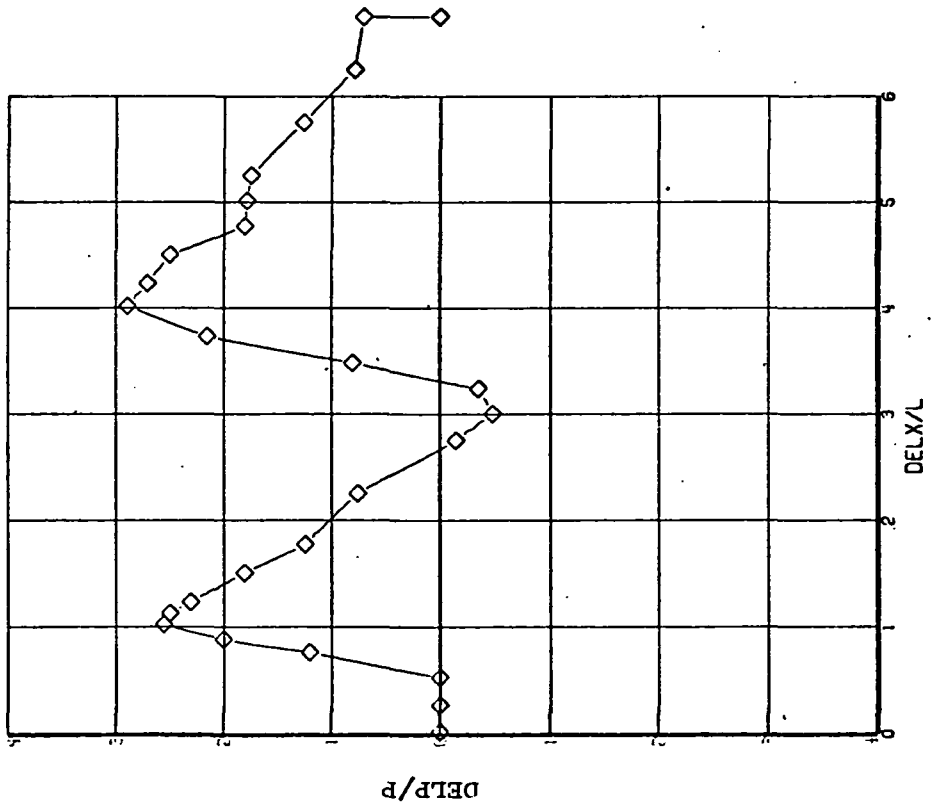
MACH = 10.020 ALPHA = 25.000 PHI = 0.000 H/L = 1.5000

PLOT 118



MACH = 7.750 ALPHA = 45.000 PHI = 180.000 H/L = .9400

PLOT 117





POSTMASTER : If Undeliverable (Section 158
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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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